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Consumption, Utilization, Biology, and Economic Injury Levels of Fall Armyworm, Spodoptera Frugiperda (J. E. Smith), on Selected Bermudagrasses.

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Consumption, utilization, biology, and economic injury levels of fall armyworm, *Spodoptera frugiperda* (J. E. Smith), on selected bermudagrasses

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CONSUMPTION, UTILIZATION, BIOLOGY, AND ECONOMIC INJURY LEVELS OF FALL ARMYWORM, *SPODOPTERA FRUGIPERDA* (J. E. SMITH), ON SELECTED BERMUDAGRASSES

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ABSTRACT

The effects of nine bermudagrass, Cynodon dactylon (L.) Pers., varieties and strains on the development, survivorship, consumption and utilization, preference, and host suitability of the fall armyworm (FAW), Spodoptera frugiperda (J. E. Smith) were determined. The bermudagrasses tested were 'Coastal', 'Tifton 44', 'Tifton 78', 'Tifton 292', 'Grazer', #1 R12P5, 'OSU 71 X 6-7', 'OSU 74 X 11-2', and 'OSU 74 X 12-1'. 'Tifton 292' was the most preferred grass by neonate larvae, while 'OSU 74 X 11-2' was the least preferred grass. 'Tifton 78' was the most susceptible host, while 'OSU 71 X 6-7' was the least suitable host to FAW based on a host suitability index. The bermudagrasses were grouped as susceptible ('Tifton 78', 'OSU 74 X 12-1', and 'Grazer'), intermediately resistant (#1 R12P5, 'Coastal', 'Tifton 292', 'OSU 74 X 11-2', and 'Tifton 44'), or resistant ('OSU 71 X 6-7') to FAW. The mechanism of resistance in 'OSU 71 X 6-7' to FAW appears to be antibiosis rather than nonpreference.

Another study evaluated the development and survivorship to the adult stage of FAW on 'Coastal', 'Grazer', 'Tifton 292' and 'OSU 71 X 6-7' bermudagrasses grown in the field and greenhouse. Bermudagrasses grown in the greenhouse were more suitable to the development of FAW than grasses grown in the field. Larvae reared on greenhouse grown grasses showed significantly ($P < 0.05$) higher larval and pupal weights in the three trials and required less time to develop. Grasses grown in the greenhouse had significantly ($P < 0.05$) higher quality than grasses grown in the field. The quality of the field grown grasses declined more rapidly from June to September than did greenhouse grown grasses.

A two-year field experiment was undertaken to determine the impact of varying densities of FAW on 'Coastal' and 'Alicia' bermudagrasses. Artificial infestations of FAW at densities of 1.1 to 9.9 larvae per 0.1 m^2 caused yield losses that ranged from 0.5 to 1.5 metric ton per ha for 'Coastal' and 0.3 to 0.9 metric ton per ha for 'Alicia'. Fall armyworm feeding on 'Coastal' also resulted in crude protein and digestible dry matter yield losses of ca. 72 and 245 kg/ha, respectively. Significant ($P > 0.05$) differences in quality and yield could not be detected in 'Alicia'. The economic injury levels of 'Coastal' 8 fourth and fifth instar larvae per 0.1 m^2, while the economic threshold were 4 fourth and fifth instar larvae per 0.1 m^2.

INTRODUCTION

Bermudagrass, *Cynodon dactylon* (L.) Pers., is extensively utilized as a forage crop in the southern United States (Monson & Burton 1982, Holt & Conrad 1986). The fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith), is a serious insect pest of bermudagrass. During FAW outbreak years, bermudagrass yield, forage quality, and stand persistence are reduced (Martin et al. 1980, Todd & Suber 1980). In recent years many agronomically improved bermudagrass varieties have been released; however, little consideration has been given to FAW resistance in these grasses.

A major component of an insect pest management program should be plant resistance because it is one of the most promising and least expensive management methods. Fall armyworm development and survivorship to the adult stage serve as criteria for determining the level of resistance in bermudagrasses (Leuck et al. 1968, Combs & Valerio 1980, Lynch et al. 1983, Quisenberry & Wilson 1985). Based on biological parameters as indicators of resistance, 'Tifton 239' (Leuck & Skinner 1970) and 'Tifton 292' (Leuck et al. 1968, Lynch et al. 1983) have been characterized as varieties resistant to the FAW. The categories of resistance were reported to be nonpreference for 'Tifton 239' and antibiosis for 'Tifton 292'. Quisenberry & Wilson (1985) also incorporated consumption and utilization into the evaluation of bermudagrass genotypes for FAW resistance. Their work indicated that 'Coastal' and 'GA 77-56' were intermediately resistant bermudagrasses, while 'Alicia' and 'OSU 71 X 6-7' were resistant.

Another component of an insect pest management program includes the use of economic injury levels (EIL) to determine the appropriate population level at which insects should be controlled. These levels can be used by producers and consultants to make more accurate decisions about the management of insect pests. Stone & Pedigo (1972) used the number of insects, yield loss, cost of control, and market value as input parameters for calculating EIL. Martin et al. (1980) and Alvarado et al. (1983) have attempted to establish EIL for FAW on bermudagrass. Martin et al. (1980) used laboratory leaf consumption and reported that the FAW EIL was 5 larvae per 0.1 m^2. They also reported EIL of 2 to 4 larvae per 0.1 m^2 based on field collected data using hay prices and cost of control. Alvarado et al. (1983) reported EIL of 0.8 and 1.5 for medium and large larvae per m^2, respectively. However, the effect of FAW feeding on bermudagrass quality was not examined in these studies.

The objectives of this study were 1) to determine the effect of nine bermudagrass varieties and strains on the growth, development, consumption, utilization, preference, and host suitability of FAW, 2) to investigate the impact of four bermudagrasses grown under field and greenhouse conditions on the development and survivorship of FAW, and 3) to determine the impact of varying FAW larval densities on forage quality and yield of 'Coastal' and 'Alicia' bermudagrasses and to utilize these data for the establishment of economic injury levels and economic thresholds.

LITERATURE REVIEW

Biology of the Fall Armyworm.

Identification. The fall armyworm was originally described by Smith & Abbot (1797) as _Phalaena frugiperda_. It was subsequently changed to _Trigonophora frugiperda_ Geyer, _Noctua frugiperda_ J. E. Smith, _Laphygma macra_ Guenee, _Laphygma inepta_ Walker, _Laphygma frugiperda_ Guenee, _Prodenia signifera_ Walker, _Prodenia plagiata_ Walker, and _Prodenia autumnalis_ Riley, _Prodenia fulvosa_ Riley, _Prodenia obscura_ Riley, and _Spodoptera frugiperda_ (J. E. Smith).

Common Name. _Spodoptera frugiperda_ (FAW) is known by the common names corn-bud-worm-moth, fall armyworm, grass caterpillar, southern armyworm, the armyworm, Daggy's corn worm, wheat cutworm, alfalfa worm, and budworm (Luginbill 1928). However, in recent years _S. frugiperda_ has been known by the common name fall armyworm (FAW).

Host Plants. The FAW is polyphagous in its food habit with a wide host range. Various host plant species attacked include bermudagrass (_Cynodon dactylon_ (L.) Pers.), crabgrass (_Digitaria_ sp. L.), bluegrass (_Poa_ sp. L.), timothy (_Phleum pratense_ L.), corn (_Zea mays_ L.), sorghum (_Sorghum bicolor_ Moench), millet (_Pennisetum glaucum_ L.), alfalfa (_Medicago sativa_ L.), oat (_Avena sativa_ L.), rye (_Secale cereale_ L.), wheat (_Triticum aestivum_ L.), rice (_Oryza sativa_ L.), peanut (_Arachis hypogaea_ L.), clovers (_Trifolium_ sp. L.), pea (_Lathyrus_ sp. L.), sugarcane (_Saccharum officinarum_ L.), tomato (_Lycopersicon esculentum_ Mill.), watermelon (_Citrullus vulgaris_ Schrad.), and grape (_Vitis_ sp L.) (Luginbill 1928). However, the FAW prefers cereals and grasses (Crumbs 1927).

Seasonal History. There are four generations of FAW in Louisiana (Oliver & Chapin 1981). Walton & Luginbill (1917) reported a tremendous outbreak of FAW along the United States east of the Rocky Mountains in 1912. Luginbill (1928) also documented FAW outbreaks in 1912, 1915, 1918, and 1920. During 1975-1977, severe FAW outbreaks occurred along the Atlantic Coast. Outbreaks usually occur during the summer and early fall when drought periods are followed by heavy rainfall. These environmental conditions suppress natural enemy populations of FAW and enhance the development of FAW (Mitchell 1986).

Ferro et al. (1979) and Barfield et al. (1978) demonstrated that when the temperature increased from 18.3 to 35.0°C, the mean development time of FAW decreased from 66.5 to 18.4 days. Therefore, during July and August, when *S. frugiperda* outbreaks usually occur, the feeding damage will be significantly increased. Temperature, moisture, and other environmental variables also can have an indirect effect on *S. frugiperda* by changing the palatability and suitability of bermudagrass as a food source or by affecting natural enemies. The erratic occurrence of *S. frugiperda* outbreaks (Sparks 1979) and the irregular distribution of heavy infestations led researchers to believe that non-crop host plant availability, timing of crop host availability, and natural mortality play dominant roles in the *S. frugiperda*'s survival strategy (Barfield & Stimac 1980).

Life Cycle. There are four stages in the FAW life cycle; egg, larvae, pupae, and adult. Luginbill (1928) and Oliver & Chapin (1981) provide descriptions of each stage. In summary, the egg is global-shaped in cross section, greenish gray, turning brown as it matures. The egg stage lasts 2-4 days. Larvae are usually dark gray to brown and range in size from 1.68 to 34.15 mm in length. The head capsule is brown with narrow submedian areas and light tan to near white adfrontal areas. The body is dense with microscopic granules. The venter is tan with yellow and reddish flecking. Pupae are of the obtect type and dark brown in color. Adults have filiform antennae. Front wings of the male are gray and brown on the upper half and pale gray on the lower half. An orbicular spot is oblique and outlined by dark scales. Front wings of the female are dark brownish gray. Hind wings are translucent white with a partial narrow black border and the veins dark distally. Wingspread is 25 to 35 mm.

Life history. The adult moths are noctrunal and fed on the nectar of grasses such as Paspalum grass, *Paspalum dilatatum* Poir., and bermudagrass, *Cynodon dactylon* (L.) Pers. The moths simultaneously respond to sugar or honey solution (Luginbill 1928). Sparks (1979) noticed that adult moths do not mate the first night after eclosion. Mating usually occurs at night time before midnight, depending upon the weather. Oviposition takes place on host plants or flags, hanging clothes, and sheds on golf courses. The female moth lays eggs in a cluster covered with scales. Masses consist of two or three layers and range from a few to a hundred eggs. Development of FAW varies with host plants and environmental conditions. Fall armyworm fed 'Coastal' resulted in a larval development period of 23.8, 16.6, and 10 days for females and 24.7, 17.3, and 10.3 for males at 20, 25, and 30°C, respectively. Pupal development took 12.9, 8.7, and 6 days for females and 13.9, 10.1, and 7 days for males at 20, 25, and 30°C, respectively. At a constant temperatures of 20, 25, and 30 °C, the average number of eggs laid per female was 1248. The egg stage lasted 2.9 days. The longivity of the female is approximately 14.6 days (Combs & Valerio 1980a). Pencoe & Martin (1982) reared FAW on different host plants at 27°C and they found that the larval development periods for larvae fed 'Coastal' bermudagrass, bahiagrass, and yellow nutsedge were 12.4, 16.2, and 18.5 days, respectively. The mean number of eggs laid per female was 800, 742, and 544 for larvae reared on 'Coastal' bermudagrass, bahiagrass, and yellow nutsedge, respectively.

Ashley (1979) noted that 53 species of parasites from 43 genera and 10 families have been reared from FAW larvae. Apanteles marginiventris (Cresson) and Chelonus texanus (Creson) are the most common parasites. There are numerous predators known to attack this pest although there are no data presently available that summarize their impact on FAW populations. Gardner & Fuxa (1980) reported that FAW larvae are susceptible to at least 16 species of entomophagous pathogens including viruses, fungi, protozoa, and bacterium.

Economic Importance of Fall Armyworm.

Crop losses caused by S. frugiperda feeding in the United States are estimated to be between \$300 to \$500 million annually (Mitchell 1979). In 1976 and 1977, S. frugiperda infestations were severe in the southeastern United States causing economic losses estimated at \$31.9 and \$297.2 million, respectively (Hunt 1978). In Georgia, loss of hay and pasture alone was estimated at \$59 million (Todd & Suber 1980).

Consumption and Utilization.

Quantitative studies measuring the consumption and utilization of food by insects are important to the fields of nutrition, ecology, host plant resistance, and pest management. Insect physiologists are interested in the affect of food quality and food components on insect development (Klein & Kogan 1974, Scriber & Slansky 1981). For ecologists, these data provide the energy relationships in studying community dynamics (Engelmann 1966). Kogan (1973) and Khalsa et al. (1979) used these data to determine the categories of plant resistance to insect pests at both the behavioral and nutritional levels. The measurement of food consumption can be utilized for economic threshold development in pest management programs (Klein & Kogan 1974). Host-plant interactions (Bhat & Bhattacharya 1978), host-plant associations (Kogan & Cope 1974), and host/parasite interactions (Rohlfs & Mack 1983, Slansky 1978) may also be determined from these data.

The feeding or consumption rate of insects can be measured as the amount of foliage consumed on a fresh weight, dry weight, or leaf area basis (Carne 1966, Kasting & McGinnis 1959, Satterthwait 1933). Feeding rate is usually determined by measuring the reaction of the insect to food plant, water content including physical and chemical properties of food (Waldbauer 1968). Consumption should be measured only on the later larval instars since early instars consume less food and it is difficult to quantify the amount consumed. Luginbill (1928) found that the first three instars of FAW larvae consumed less than 2% of the total food intake, while the last three instar consumed 98%. Hiratsuka (1920) and Wolcott (1937) found that the last two to three larval instars of Bombyx mori and Protoparce sexta consumed between 97% to 99% of the total food intake.

Utilization can be measured by three indices which include approximate digestibility (AD), efficiency of conversion of ingested food (ECI) or gross efficiency of growth, and efficiency of digested food (ECD) or net efficiency of growth. Utilization can be measured by gravimetric methods (Waldbauer 1968).

Soo Hoo & Fraenkel (1966b), Kogan & Cope (1974), and Quisenberry & Wilson (1985) found negative correlations between the consumption rate and ECI and/or ECD. As the consumption rate increased, the ECI or ECD decreased. Thus, digestibility can be affected by a nutrient deficiency, low water content, high non-digestible fractions (crude fiber), rate of food passage, and digestive efficiency (Soo Hoo & Fraenkel 1966b, Waldbauer 1964). Gordon (1968) also proposed that growth failure of an organism on a certain food source could be caused by a lower food intake, low digestibility, the blocking of absorption, and/or less efficient conversion of absorbed food into growth.

Mukerji & Guppy (1970), Latheef & Harcourt (1972), and Kogan & Cope (1974) reported that as the age or instar increases, AD decreases. They also found an inverse relationship between ECD and AD. Early instar larvae consume the nutritious tender portion of leaves, while older larvae usually consumed the whole leaf. Thus, the older larvae obtained more indigestible crude fiber than the younger larvae. However, early instar larvae utilize most of the food as energy for maintenance and less food for conversion to body substance, which is reversed in older larvae.

Food utilization (digestibility and efficiency of conversion of food into growth) varies with plant species consumed. Soo Hoo & Fraenkel (1966b) found that southern armyworm, Spodoptera eridania (Cramer) consumed higher amounts of sweet potato (Ipomoea batatas L.) than of lima bean (Phaseolus lunatus L.). Although the digestibility of sweet potato was lower, the larvae feeding on sweet potato gained more weight and required more time to complete larval development than those fed lima bean. The result was that larvae which consumed sweet potato were more efficient in converting food into body matter.

Plant nutrients (protein) have an influence on the acceptibility of a food source and subsequently the growth of the insect. Fukuda et al. (1961) found that silkworms (*Bombyx mori* L.) preferred mulberry leaves with higher nitrogen (3.14%) than with lower nitrogen (2.67%). Thus, protein may play a role on the silkworm ingestion or influence on the palatability of food. Soo Hoo & Fraenkel (1966a) also reported that host plants with higher protein enhances growth and development of southern armyworm. Hou & Chu (1984) demonstrated that silkworms fed a diet containing high levels of algal powder had more efficient digestibility and cocoon production.

Food, temperature, light, humidity, and population density also influence consumption and utilization of food sources by insects. Bhat & Bhattacharya (1978) demonstrated that food consumption of *Spodoptera litura* (Fab.) was related to temperature. Lower temperature resulted in lower food utilization and growth rate. The utilization of food by female larvae increased when reared at temperatures between 15-25°C. However, male larvae at 30°C were capable of digesting 8.1% more leaves than female larvae. The ECI increased 12.5 and 15.2% at a constant temperature of 20°C for female and male larvae, respectively. Beyond these temperatures the ECI decreased. Schroeder (1972) studied food utilization of cecropia, *Platysamia cecropia* (L.) larvae, and found that food utilization of larvae kept under different temperature and light regimes were not significantly different.

Economic Thresholds and Economic Injury Levels.

Economic threshold (ET) is one of the basic components of pest management in that it provides a guideline of the yield/pest density ratio. An ET enables a grower to estimate crop yield reduction to aid his decision making. Stern et al. (1959) defined the economic threshold as "the density at which control measures should be initiated to prevent an increasing pest population from reaching the economic injury level". Edward & Heath (1964) suggest that the economic threshold is the pest population density that cause damage equal in value to the cost of control measures. Smith & Reynolds (1968) defined the threshold of a pest as the population level just below what will cause an economic crop loss. The Subcommittee on Insect Pests of the Committee on Plant and Animal Pests (National Academy of Sciences 1969) defined the economic threshold as "the level at which damage can no longer be tolerated and, therefore, the level at or before which it is desirable to initiate deliberate control activities". Headley (1972) defined the economic threshold as "the population that produces incremental damage equal to the cost of preventing that damage". He also mentioned three variables (damage, pest population, and time) which should be involved in developing the economic threshold concept.

The quantitative relationship between insect numbers and resulting yield reduction are basic to establishing the economic threshold used in a pest management system. Stern (1966) described three criteria needed for the development of economic thresholds. The first criteria involved the quantitative measurement of the insect pest that causes crop damage. The second, he suggested, was to quantify physiological and morphological abnormalities of plants caused by insect feeding. Thirdly, it was necessary to utilize market standards that contribute to the level of insect damage tolerated at the time of crop harvest or shipment. The dollar loss related to a certain number of pest/unit area and, the cost of control on that area are therefore needed to establish the economic threshold. Since variations in the economic threshold among years results from crop price, control cost, and local climatic conditions (Stern et al. 1966, Stern 1973), these factors should also be considered. Thus, the economic threshold is the point where the two criteria (insect damage and cost of control) are equal and control becomes economically feasible (Michels & Burkhardt 1981). Stone & Pedigo (1972) also suggested integrating marketing cost, yield data, and feeding data. LeClerg (1971) proposed that economic threshold experiments should be conducted for at least 3 years since pest population and crop losses are not usually constant. He also suggested that action thresholds should consist of the examination of pest density, evaluation of quantitative and/or qualitative losses, and development of statistical techniques to analyse data. Thus, Pedigo et al. (1986) proposed that ET also express the time control should be initiated. They commented that the description of ET by Stern et al. (1959) in terms of a population density was misleading and confusing. As a result many investigators used the term ET instead of economic injury level (EIL).

Because plant stress caused by abiotic (drought, temperature, light) and biotic factors (insects, weeds, pathogens) may result in the limitation of crop yield (Higgins et al. 1984), the injury obtained and the response of the plant to that injury should be included in making pest management decisions. Ostlie & Pedigo (1985) found pronounced differences in percent defoliation and yield loss of soybean between wet and dry seasons. Consequently, insect induced plant stresses were used to establish an economic injury level (EIL) for pest management decisions in soybean (Pedigo et al. 1986)

Economic injury level (EIL) was defined by Stern et al. (1959) as "the lowest population density that will cause economic damage". Pedigo et al. (1986) criticized the definition of EIL used by Stern et al. (1959) because they felt the use of an injury level would be more appropriate than using population density to describe EIL. Stern et al. (1959) also did not describe the term of economic damage mathematically. Therefore, the first paper calcualting EIL mathematically originated more than 10 years arter the concept was introduced by Stern et al.(1959).

Pedigo et al. (1986) further defined the terms injury and damage. Injury was defined as the effect of the insect pest that was harmful to the host physiology, while damage was the amount of yield and quality lost. They also proposed a "damage boundary" concept that could be used to determine the injury level at which damage occurred. Thus, the ET would occur between the damage boundary and the EIL.

Stone & Pedigo (1972) initially quantified EIL using yield loss, control cost, and market price. Pedigo et al. (1986) proposed that four factors were needed to estimate EIL: market value, management cost, injury per insect density, and host damage per unit of injury.

In the case of FAW larvae, most of the thresholds that have been developed and used are speculative and have not been based on actual field data. Martin et al. (1980) reported EIL of 5 larvae per 0.1 m^2 for 'Coastal' bermudagrass based on laboratory leaf consumption. From field data, they also reported an EIL of 2 to 4 larvae per 0.1 m^2

depending on the probability of natural mortality after population density estimates have been determined. Alvarado et al. (1983) reported an EIL of 0.81 and 1.5 medium size and large larvae per m^2, respectively, for 'Alicia'. Suber et al. (1979) reported the action threshold of 2 larvae (0.95 cm) or larger per 0.1 m^2.

Host Plant Resistance (HPR).

Plants that inherently show less damage than other plants grown under the same environmental conditions are considered resistant (Painter 1958). The categories of plant resistance include nonpreference, antibiosis, and tolerance. Nonpreference results in behavioral changes in the insect. Antibiosis has cumualtive adverse affects on the biology of the insect. Tolerance is the ability of the plant to compensate for damage caused by insects. Kogan & Ortman (1978) have subsequently replaced the term nonpreference with antixenosis.

Wiseman (1985) pointed out that the categories of resistance may be incorporated effectively into insect pest management systems. Nonpreference results in a weakening of the insect pest, redeeming them more susceptible to chemical or biological control. Antibiosis prolongs the developmental time of the insect pest so that they may be better synchronized with the life cycle of natural enemies. Using plant tolerance reduces the cost of insecticide and permits an increase in the number of natural enemies.

Although FAW has been reported as a serious pest for more than 175 years, host plant resistance research is still quite limited as it relates to FAW. Davis (1980) showed that the efforts of plant breeders and entomologists in the United States were on 0.05 and 0.30 scientific year, respectively, to identify, develop, and release resistant crop varieties to FAW . Recently there have been many bermudagrass lines available but research has been limited on screening these lines for FAW resistance. Leuck et al. (1968) screened 441 lines of bermudagrass for neonate larval FAW resistance and found that 'Tifton 292' and 'Tifton 296' were the most resistant and nine others were intermediately resistant. Leuck & Skinner (1970) suggested that mortality of FAW larave, especially 3 to 8 day-old larvae, was higher when reared on 'Tifton 239' for three consecutive generations than when reared on 'Coastal'. Combs & Valerio (1980a) found that when larvae were fed 'common', 'Coastal', and 'Callie' bermudagrasses better development resulted than when fed 'Alicia'. Lynch et al. (1983) evaluated FAW resistance of nine bermudagrasses using consumption and preference tests. 'Tifton 292' showed a high degree of antibiosis, since no larvae survived. Although FAW larvae preferred 'Tifton 292' to the other eight bermudagrasses, it was rated as highly resistant according to a host suitability index. 'Tifton 44' was rated as intermediately resistant, while 'Coastcross-1' was the most preferred bermudagrass among the bermudagrasses. Chang et al. (1985) also reported that 'Tifton 292' and zoysiagrass (Zoysia sp.) were resistant to FAW. The categories of resistance were nonpreference and antibiosis. Quisenberry & Wilson (1985) used consumption and utilization in the evaluation of bermudagrass for FAW resistance. They found that 'Alicia' and 'OSU 71 X 6-7' were resistant to FAW and less preferred than 'Coastal', 'Georgia 77-26', and 'Georgia 77-56', which were preferred and suitable hosts.

Because FAW is a polyphagous feeder, some studies have been conducted for resistance in other host plants. Pencoe & Martin (1981, 1982) reported that various wild grasses, goosegrass (Eleusine indica

(L.) Gaertn., large crabgrass (Digitaria sanguinalis (L.) Scop., and vaseygrass (Paspalum urvillei Steud.) are suitable host plants for FAW development and reproduction. Fall armyworm larvae fed centipedegrass (Eremochola ophiuroides [Munro] Hack.) have been shown to suffer higher mortality than those fed bermudagrass or carpetgrass (Axonopus affinis Chase.) (Wiseman et al. 1982). They reported the category of resistance to be nonpreference and antibiosis. Chang et al. (1986) also found centipedegrass was resistant to FAW feeding when it was fed to either neonate larvae or when older larvae were transferred from another host to centipedegrass.

Bermudagrass.

Grassland acreage in the world is estimated to be twice that of other cultivated crops. In the United States, more than 50% of the total land area or 1.2 billion acres are utilized as grasslands. Of this total, 60% produces forage which provides almost 60% of all the feed units supplied to livestock (Baylor 1980).

Bermudagrass, a warm season perennial, is found throughout the tropical and subtropical areas of the world. It is adapted to a wide range of soils from sandy to heavy clay. Bermudagrass origianted in India where it has been grown and used as forage for centuries. The bermuadgrasses from Africa are, however, more diverse in type than those from India. Also, the species name "cynodon" is known to have its origin in Africa (Burton 1973).

Bermudagrass is one of the most important forage grasses grown in the southern part of the United States since 1800 (Burton 1973). It is also useful for silage, soil conseravtion, roadside stabilization, and turf (Palmertree 1977). Burton (1975) reported that bermudagrass acreage is over 10 million in the southern region. It is found growing from southeast Virginia to Florida and westward to Arizona and California. In Louisiana, over 2.5 million acres of bermudagrass, bahiagrass and dallisgrass are grown in pasture (Census of Agriculture of Louisiana 1978).

Bermudagrass is a pasture crop that is very tolerant to animal grazing pressure. When appropriately fertilizated and harvested every 3 or 4 weeks, bermudagrass has 12% protein, 65% digestibility, and 80% herbage (Burton & Monson 1972).

Many cultivars of bermudagrass have been developed. The oldest among these cultivars is 'common' bermudagrass. Another cultivar known as 'Coastal' was developed from 'Tift' bermudagrass and an introduction from south Africa and released in 1943 (Burton 1954).

Forage Composition and Quality.

Van Soest (1973) divided forage components into two groups based on digestible capacity, cellular, contents and cell wall constituents. Cellular contents are the highly digestible portions composed of proteins, sugars, starches, and organic acids. The cell walls are considered the major part of the plant cell, characterized as the fibrous fraction and less digestible portion. Cell walls are composed of acid detergent fiber (ADF), hemicellulose, cutin, silica, tannins, and polyphenols. The ADF is subdivided into cellulose and lignin. Lignin and crude protein are good indicators of quality (Sullivan 1962).

Crude protein is the total nitrogen (N) of the plant multiplied by 6.25. It includes true protein and nonprotein N (NPN). The percent protein is an indicator of forage quality. The higher the protein concentration, the greater the forage nutritive value (Sullivan 1962).

The protein concentration of the plant normally decreases with the age of the plant (Eirchhorn et al. 1983).

The digestibility of crude protein declines with increased maturity of most of the forages, with an abrupt decline occurring after 3 to 4 weeks of regrowth (Grieve & Osbourn 1965). It declines rapidly at 5 to 6 weeks of regrowth when flowering occurs.

The crude protein concentration appears to be a good indicator of plant response to environmental changes. This is the reason crude protein analyses of bermudagrass have been useful in determining quality even with little or no additional quantitative analytical information (Jolliff et al. 1979). The overall nutritive value variation as measured by acid detergent fiber (ADF), neutral detergent fiber (NDF), crude protein (CP), and in vitro dry matter digestibillity (IVDMD) at the six different ages was similar for both 'Coastal' and 'Coastcross-1'. The 8-week old forage was found to have the most variable nutritive value in both grasses. This indicated that harvesting grass at a late stage of regrowth causes a significant decline in the quality of most forages (Jolliff et al. 1979).

Forage quality can be determined by laboartory analysis, bioassay with animals in pens, and production from grazing animals. Among these methods, grazing trials are the most effective forage bioassay; however, the cost is high and it is time consuming. Laboratory analysis is the easiest and cheapest method to determine digestibility of forages (Minson 1971). Animal production is still another bioassay to measure forage quality and relates to the voluntary intake of pasture as well as to its digestibility (Minson 1971, Moore & Mott 1973).

Duble et al. (1971) found that cell wall constituents (CWC) and *in vitro* dry matter digestibility (IVDMD) of six perennial summer grasses were significantly correlated with animal performance (r = -0.80 and 0.78, respectively). As IVDMD decreased, average daily gain (ADG) increased. Other researchers have also found a close relationship between CWC and IVDMD (Shenk & Elliott 1970, Wilkinson et al. 1969). Lignification was one factor found to limit cell wall digestibility (r = -0.76). Duble et al. (1971) also found that the grass with the highest lignin content had the highest linear regression coefficient between IVDMD and CWC. In the case of weight in cattle, Holmes et al. (1966) found that an increase in weight was positively correlated to the amount of intake of digestible dry matter.

Rohweder et al. (1977) reported that NDF value is capable of predicting voluntary intake, although the correlation reported for bermudagrass was -0.47. The 'Coastcross-1' variety was found to be more sensitive to environmental changes and therefore varied in NDF as compared to 'Coastal' bermudagrass.

Montgomery et al. (1979) evaluated forage yield , chemical composition and digestibility of bermudagrass varieties ('Alicia', 'Coastal', and 'common') and 'Pensacola' bahiagrass under field conditions for 2 years. Results showed that the forage yields of the bermudagrasses were higher than that of 'Pensacola' bahiagrass. Among the bermudagrass, 'Alicia' produced the highest total yield (17,951 lb/A).

Structural carbohydrate percentages were generally highest in 'Alicia' and 'Pensacola' bahiagrass. Again, 'Pensacola' was highest in ADF and cellulose while 'Alicia' was found to have the highest content of CWC. Moreover, crude protein was not significantly different among the bermudagrasses. The digestibility of the four varieties was positively related to both *in vivo* and *in vitro* DDM. The seasonal change also has a greater effect on the quality of 'Pensacola' bahiagrass than on bermudagrass forages. During the early part of the season, 'Pensacola' bahiagrass yield was greater than the bermudagrasses. The lowest forage quality was observed in 'Alicia' bermudagrass. In a 7-year test of 'Coastal', 'Coastcross-1', 'Alicia', and 'common' bermudagrasses, 'Coastal' was the most desirable among all the grasses tested in yield and nutritive value, while 'Coastcross-1' performance was not consistent.

CHAPTER I

CONSUMPTION AND UTILIZATION OF NINE BERMUDAGRASS VARIETIES AND STRAINS BY THE FALL ARMYWORM (LEPIDOPTERA: NOCTUIDAE)

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ABSTRACT

Nine bermudagrass varieties and strains were evaluated to determine their effects on consumption, utilization, preference, and host suitability of the fall armyworm (FAW), Spodoptera frugiperda (J. E. Smith). Included in the study were four established varieties, 'Coastal', 'Tifton 44', 'Tifton 78', and 'Tifton 292', a newly released variety, 'Grazer', and three experimental strains, #1 R12P5, 'OSU 71 X 6-7', 'OSU 74 X 11-2', and 'OSU 74 X 12-1'. 'Tifton 292' was the grass most preferred by neonate larvae while 'OSU 74 X 11-2' was the least preferred. A host suitability index indicated that 'Tifton 78' was the most suitable host for FAW development while 'OSU 71 X 6-7' was the least suitable. The nine bermudagrass varieties and strains were categorized as susceptible ('Tifton 78', 'OSU 74 X 12-1', and 'Grazer'), intermediately resistant (#1 R12P5, 'Coastal', 'Tifton 292', 'OSU 74 X 11-2', and 'Tifton 44'), and resistant ('OSU 71 X 6-7'). Resistance to FAW feeding is believed to be antibiosis rather than nonpreference.

INTRODUCTION

The fall armyworm (FAW), Spodoptera frugiperda (J. E. Smith), an economic insect pest of bermudagrass, is a sporadic but potentially damaging agricultural pest throughout the United States (Leuck et al. 1968, Luginbill 1928, Sparks 1979). Crop losses caused by FAW feeding are estimated to be between $300 to $500 million annually (Mitchell 1979). In Georgia, loss of hay pasture alone was $59 million in 1977 (Todd & Suber 1980).

Bermudagrass is an important pasture grass for cattle production in the southern United States (Wiseman & Davis 1979, Griffin & Watson 1982). Its potential for wide spread utilization has led to the development of improved cultivars and hybrids with greater potentials for high yield, quality, persistency, and response to management and animal improved performance (Monson & Burton 1982).

Seven bermudagrass varieties have been released; however, many of these varieties have not been evaluated for FAW resistance. The first screening of bermudagrass for resistance to FAW was done by Leuck et al. (1968), who reported 11 lines with resistance to FAW. Further studies by Leuck and Skinner (1970) showed 'Tifton 239' adversely affected FAW survival and weight gain compared to 'Coastal'. Leuck et al. (1968) and Lynch et al. (1983) also ranked 'Tifton 292' as a resistant line to FAW.

Combs & Valerio (1980a) studied the effect of 'common', 'Coastal', 'Alicia', and 'Callie' bermudagrasses on the biology of FAW. They concluded that FAW growth and development were much better on 'Coastal' and 'Callie' than on 'Alicia'. An ovipositional preference study among these bermudagrasses also showed that 'Callie' was the most preferred by adult FAW moths (Combs & Valerio 1980b). Quisenberry & Wilson (1985) reported that 'Alicia' and 'OSU 71 x 6-7' were resistant to FAW and less preferred than 'Coastal', 'Georgia 77-26', and 'Georgia 77-56'.

Most of the previous studies utilized FAW growth and development parameters as criteria for determining the degree of bermudagrass susceptibility to FAW feeding (Leuck et al. 1968, Combs & Valerio 1980a, Lynch et al. 1983). Consumption and utilization parameters are important because they are needed to determine whether plant resistance affects insect behavior and/or metabolism (Kogan 1973). These indices also can be used as indicators of the interaction between the insect and its food source (Bhat & Bhattacharya 1978). Quisenberry & Wilson (1985) were the first to study FAW consumption and utilization parameters. They reported that bermudagrass with high percentages of crude protein (CP) and *in vitro* digestible dry matter (IVDDM) had decreased rates of consumption and maintenance and increased efficiency of ingested and digested food.

The objectives of this study were to determine the effect of nine bermudagrass varieties and strains on the growth, development, consumption, utilization, preference, and host suitability of FAW.

MATERIALS AND METHODS

Laboratory studies were conducted during 1985 and 1986 using nine bermudagrass varieties and strains. The bermudagrasses used in this study were either newly released varieties or experimental strains that had showed promise during field trials or varieties that had not been evaluated in consumption and utilization studies. 'Tifton 292' and 'Coastal' were used as a resistant and susceptible check, respectively

(Leuck et al. 1968, Lynch et al. 1983). Tests were divided randomly into three groups with each group tested separately because all of the bermudagrasses could not be evaluated at the same time; 'Coastal' was used as the standard grass for every group tested. The groups consisted of the following: Group 1, 'Coastal', 'Tifton 44', 'Tifton 78, and #1 R12P5; Group 2, 'Coastal', 'OSU 74 X 11-2', 'OSU 74 X 12-1', and 'Grazer'; and Group 3, 'Coastal', 'Tifton 292', and 'OSU 71 X 6-7'. Because 'Coastal' served as the standard, the 'Coastal' data from each group were analysed to test for non-significant difference all parameters measured before all data were combined and subjected to statistical analyses.

Bermudagrass Establishment. The pedigrees of the bermudagrass varieties and strains used in this study are depicted in Table 1 (Appendix). Five varieties and four strains of bermudagrass were obtained as sprigs from the USDA-ARS Laboratory, Tifton, Georgia, Agronomy Department, Oklahoma State University, and Calhoun and Iberia Louisiana Agricultural Experiment Stations. 'Tifton 44', 'Tifton 78', 'Tifton 292', and #1 R12P5 were obtained from the USDA-ARS Laboratory, 'OSU 71 X 6-7', 'OSU 74 X 11-2', and 'OSU 74 X 12-1' from Oklahoma State University, and 'Grazer' from Louisiana Agricultural Experiment Station.

Sprigs were planted in metal flats (50 by 35 by 9 cm) containing Sunshine® potting soil and maintained in the greenhouse at 16:8 (L:D), 29 ± 5°C, and > 50% RH. Grass was cut every 4 weeks to a 7 cm stubble height and fertilized with 8-8-8 fertilizer. After 2 weeks of regrowth, the leaves were excised, wrapped in moistened cheesecloth, and brought to the laboratory for the feeding studies.

Forage Quality Analysis. Bermudagrasses were harvested after 2.5 weeks of regrowth and two replications were analyzed for forage quality. Grasses were oven-dried at 60°C and ground in a Wiley mill to pass through a 1-mm screen. Quality analysis of bermudagrass tissue was performed using near infrared (NIF) spectroscopy calibrated to the respective tests. Neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose (CELL), and acid insoluble lignin (AIL) were determined as described by Goering & Van Soest (1970). Crude protein (CP) was analyzed by the improved Kjeldahl method (Association of Official Agricultural Chemists 1980). *In vitro* digestible dry matter (IVDDM) was determined by the modified Van Soest procedure (Nelson et al. 1976).

FAW Colony Maintenance. The colony originated from larvae collected on bermudagrass from East Feliciana Parish, Louisiana, in August 1984. The colony had been reared for 15 generations on modified pinto bean diet according to the procedures described by Perkins (1979).

Growth, Development, and Survival. The experiment was conducted at 26 ± 0.5°C, 14:10 (L:D), and > 50% RH. A randomized complete block design with nine treatments was used. Fifty larvae were tested on each grass. One neonate larva was placed in a clear plastic petri dish (10 by 2 cm) that contained excised leaves of a bermudagrass on moistened cellulose wadding. Grass was initially replaced after 2 days and, thereafter, renewed every day. The following parameters were used to measure the impact of the grasses on growth, development, and survival of FAW: larval weights at 6 and 8 days, pupal weights, number and duration of instars, days to pupation, days to adult eclosion, and survivorship to the adult stage.

Consumption and Utilization. Data were measured on the last larval instar because Garner & Lynch (1981) reported that 62% of all consumption occurs during this stage. Freshly molted sixth-instar larvae were weighed and provided a measured amount of leaves for 2 days with larvae being weighed at 12 h intervals. Uneaten grass and frass were removed daily, dried at 60°C for 48 h, and weighed. These data were used to determine leaf consumption and utilization on dry weight basis following the method of Waldbauer (1968). Insect utilization is expressed as I = P + M + E, where I = ingestion or consumption index (CI), quantity of food consumed, P = production or growth rate (GR), mass of material stored in larval tissue, M = maintenance, quantity of material utilized in maintaining life process, and E = egestion, quantity of material eliminated from the intestines (Wiegert 1968). The following equations were used to calculate I = P + M + E: I (or CI) = C1 - C2/WeT, P (or GR) = Wf - Wi/WeT, E = F/WeT, M = I - P - E (Schroeder 1971), and assimilation (A) = P + M or I - E (Schroeder 1972), where C1 = weight of leaves introduced, C2 = weight of leaves leftover, We = mean of five 12 h interval larval weights; T = instar duration (days), Wf = final larval weight, Wi = initial larval weight, and F = weight of frass. Approximate digestibility (AD), efficiency of conversion of digested food (ECD) or net efficiency of growth, and efficiency of conversion of ingested food (ECI) or gross efficiency of growth, were calculated using the equations: AD = 100(I - E)/I, ECD = 100P/I - E, and ECI = 100P/I (Waldbauer 1968, Schroeder 1971).

Initial fresh and final dry weights of the leaves were measured directly. Dry weights of the leaves and FAW larvae were estimated from a cohort of control leaves and six, sixth-instar larvae reared on each variety at the beginning and end of 48 h.

Preference and Host Suitability. An extended incomplete latin square experimental design (Cochran & Cox 1957) was used to evaluate feeding preference with nine treatments and 10 replications. The leaves of five bermudagrasses were arranged in each dish according to the experimental design. Leaves were excised after 17 days of regrowth. Leaf sections 2 cm long from each of five grasses were clipped and placed equidistantly on moistened cellulose wadding covered with filter paper in a clear plastic petri dish (15 by 1.5 cm). Fifty neonate larvae were obtained from the laboratory colony and released in the center of the dish. Dishes were maintained under darkness, to prevent phototactic response at 26 ± 0.5°C and > 50% R.H. After 24 h, the number of larvae on each bermudagrass was recorded.

Host suitability index, which measures the cumulative effect of antibiosis, was calculated using the equation developed by Lynch et al. (1981). Leaf consumption, pupal weights, days required to complete development, and survivorship to the adult stage were used to calculate HSI (HSI = [pupal wt (mg)/leaf consumption (mg dry wt)]/days required to complete development X percentage of survival).

Data Analysis. Data were subjected to analysis of variance using SAS GLM procedure (Freund & Littell 1981). Significant treatment means were separated using Duncan's (1955) multiple range test. Unless otherwise stated significant differences imply a probability level of ≤ 0.05.

RESULTS

Development and Survivorship of FAW on Bermudagrass. Fall Armyworm larval and pupal weights varied according to the bermudagrass consumed (Table 1). Six-day weights of larvae fed 'Grazer' and 'Tifton 78' were significantly higher (47 and 46 mg, respectively) than larvae fed the other bermudagrasses tested. Eight-day weights of larvae fed 'Grazer' were still significantly heavier. Larvae fed 'OSU 74 X 11-2', 'Tifton 292', and 'OSU 71 X 6-7' had lower 6- and 8-day weights with 'OSU 71 X 6-7' larvae weighing the least. The 8-day weight of larvae reared on 'OSU 71 X 6-7' was only half as much as larvae fed 'Grazer' (78 vs 150 mg). Pupae of larvae feeding on 'Grazer' had significantly higher (211 mg) weights than did larvae fed the other bermudagrasses (Table 1). Conversely, larvae fed 'Tifton 292' and #1 R12P5 had the lowest pupal weights.

Larvae fed 'OSU 71 X 6-7' required a significantly longer time to complete instar 1 (2.6 days) than larvae fed the other bermudagrasses (Table 2). Larvae fed 'Grazer' required less time to complete instars 1, 2, and 4 and the prepupal stage. The number of larvae feeding on 'OSU 71 X 6-7' declined from instar 1 to instar 5 with only 79% (33/42) of larvae pupating.

Larval development of FAW reared on 'OSU 71 X 6-7' was longer than observed when larvae were fed the other bermudagrasses (Table 3). Larvae required 15 days to develop on 'OSU 71 X 6-7' and 14 days on #1 R12P5, 'Tifton 44', and 'OSU 74 X 11-2', while the development of larve reared on 'Grazer' was only 12 days. FAW pupal duration was similar to the pattern observed for larval development. Larvae reared on 'Tifton 78' and 'Tifton 44' had longer periods of pupal development (8.5 days)

Table 1. Six- and eight-day larval weights and pupal weights of *S. frugiperda* larvae fed nine bermudagrasses.

Bermudagrass	Larval wt. (mg)				Pupal wt. (mg)	
	n[a]	6-day	n	8-day	n	
'Coastal'	47	33.29 bc	46	130.79 bc	46	197.04 bc
'Tifton 44'	48	29.90 cd	47	125.87 cd	46	190.37 cd
'Tifton 78'	48	45.65 a	48	142.06 ab	48	190.19 cd
'Tifton 292'	41	21.66 f	41	101.44 e	38	181.47 e
#1 R12P5	48	26.65 de	48	113.10 de	47	181.64 e
'Grazer'	47	46.96 a	47	150.19 a	46	210.61 a
'OSU 71 x 6-7'	47	15.60 g	47	77.53 f	33	187.88 de
'OSU 74 x 11-2'	46	23.04 ef	46	103.33 e	46	190.54 cd
'OSU 74 x 12-1'	48	34.90 b	48	123.94 cd	46	201.48 b

Means within column followed by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test).

[a] n = number of observations.

Table 2. Instar duration of *S. frugiperda* larvae fed nine bermudagrasses.

		Duration (days)						
Bermudagrass	n	Instar 1	n	Instar 2	n	Instar 3	n	Instar 4
'Coastal'	47	2.09 c	47	1.39 c	47	1.65 abc	47	1.79 b
'Tifton 44'	49	2.08 c	49	1.43 bc	49	1.84 a	48	2.00 ab
'Tifton 78'	49	2.14 c	48	1.46 bc	48	1.56 bc	48	1.46 c
'Tifton 292'	43	2.37 b	42	1.60 ab	41	1.44 c	41	2.00 ab
#1 R12P5	47	2.06 c	47	1.62 ab	47	1.68 ab	47	2.23 a
'Grazer'	48	2.02 c	48	1.02 d	48	1.88 a	47	1.17 d
'OSU 71 x 6-7'	49	2.57 a	47	1.74 a	47	1.83 a	45	2.02 ab
'OSU 74 x 11-2'	49	2.10 c	48	1.79 a	48	1.46 bc	46	2.11 a
'OSU 74 x 12-1'	48	2.04 c	48	1.38 c	48	1.58 bc	48	1.56 c

Table 2. Continued.

	Duration (days)					
Bermudagrass	n[a]	Instar 5	n	Instar 6	n	Prepupal stage
'Coastal'	46	1.86 c	46	3.00 b	46	1.20 c
'Tifton 44'	47	2.17 b	47	3.06 a	46	1.57 a
'Tifton 78'	48	2.04 b	48	3.00 b	48	1.35 b
'Tifton 292'	41	2.00 bc	39	3.00 b	38	1.00 d
#1 R12P5	47	2.17 b	47	3.00 b	47	1.57 a
'Grazer'	47	2.00 bc	46	3.00 b	46	1.00 d
'OSU 71 x 6-7'	42	2.02 bc	33	3.00 b	33	1.70 a
'OSU 74 x 11-2'	46	2.35 a	46	3.02 b	46	1.04 d
'OSU 74 x 12-1'	47	2.04 b	46	3.00 b	46	1.02 d

Means within column followed by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test).

[a] n = number of observations.

Table 3. Duration of S. frugiperda larval and pupal stages fed nine bermudagrasses.

Bermudagrass	n[a]	Larval duration (day)	n	Pupal duration (day)
'Coastal'	46	12.97 ef	46	8.07 bc
'Tifton 44'	46	14.13 bc	46	8.52 a
'Tifton 78'	48	13.00 e	48	8.52 a
'Tifton 292'	38	13.42 de	38	7.92 c
#1 R12P5	47	14.36 ab	46	8.35 ab
'Grazer'	46	12.20 g	44	7.86 c
'OSU 71 x 6-7'	33	14.73 a	33	8.42 ab
'OSU 74 x 11-2'	46	13.83 cd	46	8.41 ab
'OSU 74 x 12-1'	46	12.54 fg	46	8.22 abc

Means within column followed by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test).

[a] n = number of observations.

followed by 'OSU 71 X 6-7' (8.4 days), while pupae required only 7.9 days to develop on 'Grazer' and 'Tifton 292'.

Larvae fed 'Tifton 44', #1 R12P5, and 'OSU 71 X 6-7' required a significantly longer period (23 days) to reach adult eclosion than larvae reared on the other bermudagrasses (Table 4). Larvae reared on 'Grazer' took the least amount of time (20 days) to eclose as adults. Adult eclosion of larvae reared on 'OSU 74 X 11-2', 'OSU 74 X 12-1', 'Coastal', and 'Tifton 292', took ca. 21-22 days. Survivorship of FAW larvae among all grasses ranged from 80-90%, with the highest (96%) occurring on 'Tifton 78' and the lowest (66%) occurring among larvae fed 'OSU 71 X 6-7'.

Consumption and Utilization. Larvae reared on 'Grazer', 'Coastal', 'Tifton 44', 'OSU 74 X 11-2', and 'OSU 74 X 12-1' had significantly higher leaf consumption rates (242-256 mg) than larvae reared on the other bermudagrasses (Table 5). Lower leaf consumption rates (199-212 mg) were observed when larvae were reared on 'Tifton 78', #1 R12P5, 'OSU 71 X 6-7', and 'Tifton 292'. Larvae fed 'Tifton 292' consumed a significantly lower amount of leaf tissue (190 mg) than larvae fed the other bermudagrasses.

Leaf consumption and utilization of sixth-instar larvae expressed as daily rates (mg/day) were significantly influenced by bermudagrasses (Table 6). The daily ingestion (I1) rates of FAW larvae fed 'Grazer', 'Coastal', 'Tifton 44', 'OSU 74 x 11-2', and 'OSU 74 X 12-1' were significantly higher than larvae fed the other bermudagrasses; thus, the daily growth rates (P1 = 26-27 mg/day) and assimilation rates (A1 = 64-68 mg/day) of larvae reared on these bermudagrasses (except A1 of larvae fed 'Tifton 44') were high. The daily egestion rate (E1) of

Table 4. Days to adult eclosion and survivorship of <u>S. frugiperda</u> fed nine bermudagrasses.

Bermudagrass	n[a]	Days to adult eclosion	n	Survivorship (%)
'Coastal'	46	21.04 cd	50	92 a
'Tifton 44'	46	22.65 a	50	92 a
'Tifton 78'	48	21.52 c	50	96 a
'Tifton 292'	38	21.34 c	50	76 b
#1 R12P5	46	22.67 a	50	94 a
'Grazer'	44	20.07 e	50	88 a
'OSU 71 x 6-7'	33	23.15 a	50	66 b
'OSU 74 x 11-2'	46	22.09 b	50	92 a
'OSU 74 x 12-1'	46	20.76 d	50	92 a

Means within column followed by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test).

[a] n = number of observations.

Table 5. Leaf consumption of sixth instar _S. frugiperda_ fed nine bermudagrasses.

Bermudagrass	No. of observations (n)	Leaf consumption (mg)
'Coastal'	44	249.00 a
'Tifton 44'	47	245.79 a
'Tifton 78'	48	198.76 b
'Tifton 292'	39	189.73 c
#1 R12P5	47	212.04 b
'Grazer'	47	255.73 a
'OSU 71 x 6-7'	33	211.89 b
'OSU 74 x 11-2'	46	243.92 a
'OSU 74 x 12-1'	46	242.45 a

Means within column followed by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test).

Table 6. Daily consumption and utilizaiton rates of sixth instar *S. frugiperda* fed nine bermudagrasses.

Bermudagrass	No. of observations (n)	Daily rates (mg/day)				
		I1	E1	M1	P1	A1
'Coastal'	46	124.95 a	58.29 bc	40.27 a	26.40 a	66.66 a
'Tifton 44'	47	122.90 a	63.34 a	33.96 b	25.60 a	59.56 b
'Tifton 78'	48	99.38 bc	56.51 bc	16.93 d	25.94 a	42.87 cd
'Tifton 292'	39	94.87 c	54.46 c	17.79 d	22.62 b	40.41 d
#1 R12P5	47	106.02 b	58.94 abc	23.94 c	23.14 b	47.08 c
'Grazer'	47	127.87 a	59.66 ab	42.32 a	25.89 a	68.21 a
'OSU 71 x 6-7'	33	105.95 b	49.52 d	32.35 b	24.08 b	56.43 b
'OSU 74 x 11-2'	46	121.96 a	57.49 bc	38.80 a	25.67 a	64.47 a
'OSU 74 x 12-1'	46	121.23 a	54.79 bc	39.50 a	26.94 a	66.43 a

Means within column followed by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test). I1, ingestion rate; E1, egestion rate; M1, maintenance rate; P1, production or growth rate; A1, assimilation rate.

larvae fed 'Tifton 44' was the highest (63 mg/day) and larvae fed 'OSU 71 X 6-7' had the lowest EI rates. Conversely, larvae reared on 'Tifton 78', 'Tifton 292', #1 R12P5, and 'OSU 71 X 6-7' had lower daily II rates; however, the daily growth rates of larvae fed 'Tifton 78' and 'OSU 71 X 6-7' were higher (26 and 24 mg/day, respectively), while the daily growth rate of larvae fed 'Tifton 292' and #1 R12P5 were the lowest (23 mg/day). Larvae fed 'Tifton 78', 'Tifton 292', and #1 R12P5 had significantly lower AI (40 to 47 mg/day) while the AI of 'OSU 71 X 6-7' was moderately high (56 mg/day). Maintenance (MI) of larvae fed 'Grazer', 'Coastal', 'OSU 74 X 11-2', and 'OSU 74 X 12-1' were significantly higher (39 to 42 mg/day) than larvae reared on 'Tifton 78', 'Tifton 292' (17 to 18 mg/day, respectively). Maintenance rates of larvae fed 'OSU 71 X 6-7', 'Tifton 44', and #1 R12P5 fell between these two groups.

Relative consumption and utilization rates (mg/mg/day) of larvae fed 'Tifton 78', 'Coastal', 'Tifton 44', and 'OSU 74 X 12-1' (Table 7) showed the same pattern as observed with daily rates in Table 6. In contrast, the relative consumption and utilization rates of larvae reared on 'Tifton 292', #1 R12P5, 'Grazer', 'OSU 74 X 11-2' showed different patterns from those observed with daily rates. Larvae fed 'Tifton 292' had low ingestion (I) but high egestion (E) and production or growth rate (P). Larvae fed #1 R12P5 had high I, E, P but low assimilation (A) and maintenance (M). Larvae reared on 'Grazer' had moderately high I, high A and M but low E and P. Larvae reared on 'OSU 74 X 11-2' had moderately high I and low E but high M, P, and A.

The approximate digestibility (AD) of larvae fed 'Coastal', 'Grazer', 'OSU 71 X 6-7', 'OSU 74 X 11-2', and 'OSU 74 X 12-1' was

Table 7. Relative consumption and utilization rates of sixth instar *S. frugiperda* fed nine bermudagrasses.

Bermudagrass	No. of observations (n)	Relative mass-time rates (mg/mg/day) I	E	M	P	A
'Coastal'	46	3.02 ab	1.41 c	0.97 a	0.64 abc	1.61 a
'Tifton 44'	47	3.07 a	1.59 b	0.84 b	0.64 abc	1.48 b
'Tifton 78'	48	2.37 f	1.35 c	0.40 e	0.62 bcd	1.02 e
'Tifton 292'	39	2.70 e	1.54 b	0.51 d	0.65 abc	1.16 d
#1 R12P5	47	3.02 ab	1.68 a	0.68 c	0.65 ab	1.34 c
'Grazer'	47	2.85 cd	1.33 cd	0.94 ab	0.58 e	1.52 ab
OSU 71 x 6-7'	46	2.90 bc	1.34 c	0.89 ab	0.66 a	1.56 ab
OSU 74 x 11-2'	46	2.81 cde	1.32 cd	0.89 ab	0.60 de	1.48 b
OSU 74 x 12-1'	46	2.75 de	1.24 d	0.90 ab	0.61 cd	1.51 ab

Means within column followed by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test). I, ingestion rate; E, egestion rate; M, maintenance rate; P, production or growth rate; A, assimilation rate.

significantly higher than that of larvae fed the other bermudagrasses (Table 8). The AD of larvae fed 'Grazer' was high (53%), while the ECI and ECD were low. FAW larvae consumed the largest amount of foliage (128 mg/day) (Table 6) but they failed to convert food into body matter, as shown by low ECI (20%) and ECD (38%) levels. The data also suggest that bermudagrasses that can be digested well (52 to 53% AD) by FAW tend to have lower ECI and ECD values. The AD values of 'Tifton 78' and 'Tifton 292' were lowest (43%) but these grasses had higher ECI and ECD values. Larvae fed 'Tifton 78' and 'Tifton 292' also consumed the least amount of foliage (99 and 95 mg/day) but were capable of converting food to body matter more efficiently as indicated by higher ECI (27 and 24%) and ECD (67 and 56%) values.

Preference and Host Suitability. Neonate FAW larvae showed no significant difference in preference between the resistant grasses 'Tifton 292' (15.8) and 'OSU 71 X 6-7' (13.7) and the susceptible grass 'Grazer' (11.3) (Table 9). All three were significantly more preferred than 'Coastal', 'Tifton 44' or 'OSU 71 X 11-2'. The cumulative effect of antibiosis in plant tissue, the host suitability index (HSI), showed that 'Tifton 78' was a significantly more suitable host (HSI = 7%) than all other grasses tested. 'OSU 71 X 6-7' and 'Tifton 44' were significantly less suitable hosts (HSI = 4% and 5%, respectively) than susceptible 'Grazer' and 'Coastal'.

Forage Quality. The quality composition of bermudagrasses is presented in Table 10. The water content of 'Grazer' (80%) and 'Tifton 78' (78%) was higher than that of the other bermudagrasses tested. 'Tifton 44' and #1 R12P5 had moderately high water content (73%) with the water content of the other bermudagrasses ranging from 67 to 69%.

Table 8. Approximate digestibility (AD), efficiency of conversion of ingested (ECI) and digested (ECD) food consumed by sixth instar S. frugiperda fed nine bermudagrasses.

Bermudagrass	No. of observations (n)	Nutritional index (%)		
		AD	ECI	ECD
'Coastal'	46	53.20 a	21.24 de	40.46 e
'Tifton 44'	47	47.80 b	21.14 de	48.03 cd
'Tifton 78'	48	43.41 c	26.93 a	66.69 a
'Tifton 292'	39	42.82 c	23.94 b	56.50 b
#1 R12P5	47	44.35 c	22.02 cd	53.77 bc
'Grazer'	47	53.34 a	20.33 e	38.18 e
'OSU 71 x 6-7'	33	53.77 a	22.98 bc	42.58 de
'OSU 74 x 11-2'	46	52.72 a	21.48 de	40.95 e
'OSU 74 x 12-1'	46	54.90 a	22.37 cd	40.85 e

Means within a column followed by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test).

Table 9. Larval preference and host suitability of S. *frugiperda* on nine bermudagrasses.

Bermudagrass	Preference	HSI[a] (%)
'Coastal'	6.40 cd	5.65 cd
'Tifton 44'	6.50 cd	5.14 e
'Tifton 78'	9.70 bc	7.36 a
'Tifton 292'	15.80 a	5.45 de
#1 R12P5	10.00 bc	5.69 cd
'Grazer'	11.30 abc	5.96 bc
'OSU 71 x 6-7'	13.70 ab	4.08 f
'OSU 74 x 11-2'	4.30 d	5.38 de
'OSU 74 x 12-1'	9.00 bcd	6.17 b

Means within column followed by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test).

[a] HSI = [pupal wt (mg)/leaf consumption (mg dry wt)]/days required to complete development X percentage of survival.

Table 10. Forage quality composition of nine bermudagrasses.

Bermudagrass	Water content (%)	NDF (%)	ADF (%)	CELL (%)	AIL (%)	CP (%)	IVDDM (%)
'Coastal'	66.81 f	70.12 ab	27.76 b	24.78 c	2.84 cd	17.32 d	62.65 c
Tifton 44'	73.10 c	70.06 ab	27.52 b	26.90 b	3.29 c	22.43 abc	66.23 b
'Tifton 78'	77.84 b	66.11 c	22.89 c	23.10 d	3.35 c	26.46 a	69.75 a
'Tifton 292'	67.99 e	72.03 a	35.03 a	28.32 a	4.34 a	19.34 bcd	60.31 d
#1 R12P5	72.60 c	71.84 a	28.13 b	25.81 bc	2.98 cd	18.58 cd	65.38 b
'Grazer'	79.88 a	69.30 b	27.99 b	24.90 c	2.50 d	21.88 abc	65.79 b
'OSU 71 x 6-7'	67.30 ef	68.00 bc	27.97 b	22.96 d	3.39 bc	23.91 ab	66.60 b
'OSU 74 x 11-2'	67.76 e	71.61 a	30.61 b	26.55 b	4.04 ab	20.27 bcd	61.80 cd
'OSU 74 x 12-1'	69.31 d	68.68 b	28.68 b	24.66 c	3.07 cd	21.62 bcd	65.04 b

Means within column followed by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test). NDF, neutral detergent fiber; ADF, acid detergent fiber; CELL, cellulose; AIL, acid insoluble lignin; CP, crude protein; IVDDM, *in vitro* digestible dry matter.

The nutritional composition of bermudagrass, expressed as non-digestible fractions (% NDF, ADF) and digestible fractions (protein) varied according to variety. 'Tifton 292', #1 R12P5, and 'OSU 74 X 11-2' had higher concentrations of NDF (72%) and ADF (28 to 35%) with lower % CP (19 to 20%) and IVDDM (60 to 62%) (except #1 R12P5) than the other bermudagrasses. 'Tifton 78' had the lowest concentration of NDF (66%) and highest % CP (26%) and IVDDM (70%).

DISCUSSION

The plant resistance categories, nonpreference, tolerance, and antibiosis have cumulative detrimental effects on insects (Painter 1951). Using insect-resistant varieties is one of the least expensive methods of control that can be used in pest management programs. Insect resistant varieties do not have detrimental effects on the environment and usually have long-term benefits. Bermudagrass hybrids have been developed for improved agronomic characteristics but few have been bred for resistance to major insect pests such as the FAW.

Recently, a number of bermudagrass varieties have been developed for higher yield and quality (Monson & Burton 1982). Burton (1963) observed that FAW preferred bermudagrass with high quality just as cattle did. Lynch et al. (1983), Lynch (1984), Lynch et al. (1986), and Quisenberry & Wilson (1985) confirmed that bermudagrass with higher % CP and IVDDM was more susceptible to FAW. Fall armyworm outbreaks also were more prevalent in well-managed fields where high levels of nitrogen fertilization were applied (Lynch 1984). Our data also confirms that bermudagrasses with high quality tend to be more susceptible to FAW feeding. For example, we found that larvae reared on

'Grazer' had the highest larval and pupal weights and percent survival and the shortest larval and pupal duration and days to adult eclosion of all bermudagrasses tested (Tables 1, 3, and 4). Similar results were observed when larvae were reared on 'Tifton 78', except that survivorship was higher (96%) (Table 4). These two grasses also had higher % CP, IVDMD, and water and lower non-digestible fractions (NDF, ADF, CELL) (Table 10). Lynch (1984) reported FAW reared on bermudagrass containing high % CP and IVDDM had higher weight gains and survivorship and shorter larval duration than larvae fed lower quality grass. Lynch et al. (1983) also showed that 'Tifton 67', 'Tifton 68', and 'Tifton 84' bermudagrasses with high % CP and IVDMD were more susceptible to FAW feeding. The consumption and utilization of larvae reared on 'Tifton 78' also had a lower ingestion rate and AD level (29 mg/day and 10%, respectively) than larvae reared on 'Grazer' (Tables 6 and 8). However, the conversion of food (ECI and ECD) of larvae reared on 'Tifton 78' was 7 and 29% more efficient than larvae reared on 'Grazer' because larvae fed 'Tifton 78' had a 25% lower maintenance cost. Thus, the growth rate of larvae reared on these two grasses were the same (26%) (Table 6). Quisenberry & Wilson (1985) also demonstrated that FAW feeding on bermudagrass with high % CP and IVDDM results in a lower ingestion rate. Lynch et al. (1983) reported that feeding 'Tifton 84' to FAW provided high nutrition per unit leaf area and resulted in a lower quantity of leaf area being consumed. Soo Hoo & Fraenkel (1966) and Kogan & Cope (1974) found the less amount of food needed for energy, the more it could be assimilated into new protoplasm.

Larvae reared on 'Tifton 292' and #1 R12P5 (cross between 'Tifton 44' and 'Tifton 292') had lower larval and pupal weights than larvae fed the other bermudagrasses (Table 1). Comparison between 'Tifton 292' and #1 R12P5, revealed that larvae fed #1 R12P5 had higher survivorship than larvae fed 'Tifton 292' (Table 4). The #1 R12P5 plant tissue had higher % IVDDM and water content, but lower ADF, CELL, and AIL concentrations (Table 10). Fall armyworm reared on #1 R12P5 had an 11 mg/day higher I1 and 6% higher maintenance as compared with 'Tifton 292', while growth rate, AD, ECI and ECD were similar (Tables 6 and 8). Larvae reared on #1 R12P5 also had a higher HSI (Table 9) than 'Tifton 292'. Both of these bermudagrasses should be considered intermediately resistance to FAW. 'Tifton 292' was also the most preferred of the nine bermudagrasses by neonate larvae. Lynch et al. (1983) reported that 'Tifton 292' was highly resistant to FAW as indicated by a zero HSI value, even though a high degree of preference to neonate FAW larvae was observed.

Larvae fed 'Tifton 44', a hybrid from a cross between 'Coastal' and a plant introduction from Germany (Burton & Monson 1978), had lower larval and pupal weights and extended larval and pupal development than larvae fed 'Coastal' (Tables 1 and 3). Ingestion (mg/day) by larvae reared on 'Tifton 44' was lower than those fed 'Coastal', but egestion was higher (Table 6). Surprisingly, the growth rate of larvae fed both bermudagrasses was the same (25 mg/day), but larvae fed 'Tifton 44' were more efficient in converting food to body substance as indicated by a higher ECD value (Table 8). From a nutritional aspect, 'Tifton 44' had 5, 3, and 6% higher CP, IVDDM, and water than 'Coastal', respectively (Table 10). Larvae fed 'Tifton 44' also had a 5% lower AD because the leaf tissue was more fibrous (higher AIL) and deterred digestion. There was no significant difference between the two grasses in host preference (Table 9). 'Tifton 44' and 'Coastal' can be ranked as intermediately resistant to FAW. Lynch et al. (1983) also ranked 'Tifton 44' as intermediately resistant to FAW feeding; however, larvae reared on 'Tifton 44' in our study had higher larval and pupal weights and shorter larval duration than larvae fed 'Tifton 44' in their study.

FAW larvae reared on three OSU strains ('OSU 71 X 6-7', 'OSU 74 X 11-2', and 'OSU 74 X 12-1') were crosses that had one common parent, Accession 12165. Larvae fed 'OSU 74 X 12-1' had the highest larval and pupal weights and shortest duration of larval and pupal development and days to adult eclosion (Tables 1, 3, and 4). Consumption and utilization indices of larvae reared on 'OSU 74 X 11-2' and 'OSU 74 X 12-1' were not significantly different (Tables 6, 7, and 8). All parameters measured for these two strains were higher than the same values measured for 'OSU 71 X 6-7'. The survivorship of larvae reared on 'OSU 74 X 11-2' and 'OSU 74 X 12-1' was 16% higher than that of larvae fed 'OSU 71 X 6-7' (Table 4). The forage quality of 'OSU 71 X 6-7' was higher with higher % CP and IVDDM and a lower NDF concentration than 'OSU 74 X 11-2' and 'OSU 74 X 12-1' (Table 10). Theoretically, 'OSU 71 X 6-7' should have been a more suitable host for FAW as compared with the other two strains. 'OSU 71 X 6-7' was the least suitable host as indicated by the HSI index (4%) (Table 9). Although 'OSU 71 X 6-7' was the second most preferred grass to neonate larvae, only 66% of introduced larvae survived to pupation. In fact, 21% of the larvae fed 'OSU 71 X 6-7' died after the fifth instar (Table 2). Furthermore, larvae reared on 'OSU 71 X 6-7' weighed the least and required the longest period of larval development. 'OSU 71 X 6-7' was ranked as resistant to FAW with the resistance category being antibiosis rather than nonpreference.

Quisenberry & Wilson (1985) also reported that 'OSU 71 X 6-7' was resistant to FAW.

Fall armyworm larvae reared on several of the bermudagrass varieties and strains showed adverse effects expressed as low survival, increased duration of larval and pupal development, increased leaf consumption and/or lower pupal weights. Thus, antibiosis rather than nonpreference is believed to be the mechanism of resistance. The HSI indicated that 'Tifton 78' was the most suitable host for FAW while 'OSU 71 X 6-7' was the least suitable. Based on their degree of resistance to the FAW, three groups of bermudagrass can be recognized. The susceptible group consists of, 'Tifton 78', 'OSU 74 X 12-1', and 'Grazer'. The intermediately resistant group consists of, #1 R12P5, 'Coastal', 'Tifton 292', 'OSU 74 X 11-2', and 'Tifton 44'. The third group consists of the resistant bermudagrass 'OSU 71 X 6-7'.

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CHAPTER II

IMPACT OF BERMUDAGRASS GROWN IN THE FIELD AND GREENHOUSE ON THE BIOLOGY OF THE FALL ARMYWORM (LEPIDOPTERA: NOCTUIDAE)

This Chapter is Written in the Style of

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ABSTRACT

A study was conducted to compare the growth and development of the fall armyworm (FAW), Spodoptera frugiperda (J. E. Smith), consuming bermudagrass grown in the field and greenhouse. FAW larvae were fed three bermudagrass varieties, 'Coastal', 'Grazer', and 'Tifton 292' and one strain, 'OSU 71 X 6-7'. Bermudagrasses grown in the field were less acceptable to FAW than the same grasses grown in the greenhouse. Larvae fed bermudagrasses grown in the greenhouse had significantly higher larval and pupal weights in the three trials (10 to 231 mg and 27 to 51 mg, respectively) and decreased duration of larval development (2 to 5 days). The quality of field grown grasses was lower and declined more rapidly from June to September than the same grasses grown in the greenhouse.

INTRODUCTION

Bermudagrass, Cynodon dactylon (L.) Pers., is widely grown for pasture in the southern United States (Monson & Burton 1982). The major insect pest of bermudagrass is the fall armyworm (FAW), Spodoptera frugiperda (J. E. Smith), which can cause severe economic losses from pastures through reduced yield and quality (Martin et al. 1980, Jamjanya 1987).

One method of controlling insect pests is by host plant resistance. Initial studies by Leuck et al. (1968) and Lynch et al. (1983) characterized 'Tifton 292' bermudagrass as resistant to FAW. Lynch et al. (1983) reported 100% mortality after larvae were fed 'Tifton 292'. In contrast, Jamjanya (1987) reported that FAW feeding on 'Tifton 292' had a 76% survivorship. These discrepancies in results concerning the status of bermudagrass resistance to FAW can possibly be explained by differences in 1) insect host strain, 2) preconditioning on artificial diet, and/or 3) the forage quality of grass from different sources, field versus greenhouse grown plants.

Pashley et al. (1987) recently reported that FAW collected from bermudagrass/rice and corn hosts were genetically different and exhibited different host specificity to 'Tifton 292' bermudagrass. Quisenberry & Whitford (1987) reported that FAW larvae of these two host strains reared on four artificial diets developed at different rates on 'Coastal' and 'Tifton 292' bermudagrass.

Many researchers have documented that the quality of bermudagrass is affected by seasonal variation (period between harvests and time of year). Brown et al. (1976) found that percent digestible dry matter of 'Coastal' bermudagrass increased in June and July but declined in

August, September, and October. Monson & Burton (1982) reported that *in vitro* dry matter digestibility (IVDMD) of 'Coastal' decreased during the growing season. Furthermore, Joliff et al. (1979) found a monthly variation in forage quality as indicated by varying levels of crude protein (CP), acid detergent fiber (ADF), and IVDMD. Crude protein was reported highest in May and September (Montgomery et al. 1979) and lowest in June for all forage ages (Nelson et al. 1980).

Previous findings showed that 'Tifton 67', 'Tifton 68', and 'Tifton 84', which have high IVDMD and CP content, were also more susceptible to FAW feeding (Lynch et al. 1983). Additional work by Lynch et al. (1986) found that CP and IVDMD were positively correlated with FAW larval weight gain. Quisenberry & Wilson (1985) reported decreased rates of consumption and maintenance and increased efficiency of ingested and digested food when FAW were fed bermudagrass with high CP and IVDDM.

The influence of bermudagrass grown under field versus greenhouse conditions on FAW development has not been documented. Therefore, this study was conducted to investigate the impact of four bermudagrasses grown under field and greenhouse conditions on the development and survivorship of FAW.

MATERIALS AND METHODS

Three trials were conducted during 1986: 13 June to 26 July (trial 1), 11 July - 19 August (trial 2), and 8 August to 23 September (trial 3). 'Coastal', 'Grazer', 'OSU 71 X 6-7', and 'Tifton 292' were grown under field (FD) and greenhouse (GH) conditions. These bermudagrasses were chosen for the following reasons: 'Coastal' is a widely grown variety in the southern United States and has been used as a standard in variety screening trials (Lynch et al. 1983, Quisenberry & Wilson 1985); 'Grazer' is a new variety just released in Louisiana and is susceptible to FAW feeding (Jamjanya 1987); 'OSU 71 X 6-7' is resistant to FAW feeding (Quisenberry & Wilson 1985, Jamjanya 1987); 'Tifton 292' was reported resistant to FAW Leuck et al. 1968 and Lynch et al. 1983, but immediately resistant to FAW by Jamjanya 1987. 'Coastal' and 'Tifton 292' sprigs were obtained from USDA-ARS Laboratory, Tifton, Georgia, and 'Grazer' and 'OSU 71 X 6-7' were obtained from Louisiana Agricultural Iberia and Calhoun Research Stations, and Department of Agronomy, Oklahoma State University, respectively.

Bermudagrass Establishment. Field plots (4 by 12 m) were established in April, 1986 at the Rice Research Station, Crowley. Bermudagrass sprigs were planted at random within the plot. Foliage was harvested to a 7 cm stubble height every 4 weeks and fertilized with 8-8-8 fertilizer at the rate of 50 kg/ha. After 2 weeks of regrowth, leaves were excised every other day, wrapped with moistened cheesecloth, and brought back to the laboratory for the feeding study.

In the greenhouse, bermudagrass sprigs were planted in metal flats (50 by 35 by 9 cm) containing Sunshine® potting soil and maintained at 16:8 (L:D), 29 ± 5°C, and > 50% RH. Grass was harvested and fertilized according to surface area as described above. Occasionally, plants had to be sprayed with carbaryl (Sevin 80% S, 30 ml/3.8 liters) to run-off after harvesting because of a planthopper infestation.

Forage Quality Analysis. Forage quality was determined for all grasses grown under each environmental conditions at 1 month post harvest by analyzing two replications of each bermudagrass. Grasses were cut and weeds removed from each field plot sample before oven drying at 60°C. Dried plant material was ground in a Wiley mill to pass through a 1-mm screen. Quality analyses of bermudagrass tissue were taken using near-infrared (NIF) spectroscopy calibrated to the respective tests. Neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose (CELL), and acid insoluble lignin (AIL) were determined as described by Goering & Van Soest (1970). Crude protein (CP) was analyzed by the improved Kjeldahl method (Association of Official Agricultural Chemists 1980). In vitro digestible dry matter (IVDDM) was determined by the modified Van Soest procedure (Nelson et al. 1976).

Fall Armyworm Colony Maintenance. The bermudagrass/rice FAW strain was maintained in colony from larvae collected on bermudagrass in East Feliciana Parish, Louisiana, in August 1984. The colony had been reared for 23 generations on a modified pinto bean diet according to the procedures described by Perkins (1979).

Experimental Design. A completely randomized block design with factorial arrangement of treatments (source of grass and bermudagrasses) was used with five replications. Each treatment consisted of a subsample of five dishes with an average calculated within each subsample. One neonate FAW larva was placed in a plastic petri dish (10 by 2 cm) that contained excised leaves of a bermudagrass from either field or greenhouse on moistened cellulose wadding. Leaves were replaced initially after 2 days and then replaced every day. The experiment was conducted at 26 ± 0.5°C, 14:10 (L:D), and > 50% RH. Fall armyworm parameters measured included 6-, 8-, and 10-day larval weights, pupal weights, larval duration, pupal duration, and percent survival to adult.

Data were subjected to analysis of variance using SAS GLM procedure (Freund & Littell 1981). Significant treatment means were separated using a t-test or Duncan's (1955) multiple range test. Unless otherwise stated treatment means imply a probability level of ≤ 0.05 .

RESULTS

Significant differences were detected among trials ($P < 0.05$); therefore, results are reported separately by trial. During trial 2, bermudagrass plots in the field were accidentally sprayed with carbaryl (Sevin 80% S, 0.092 kg/ha) 8 days into the larval feeding period and the residual effect of the insecticide on the grass resulted in 100% larval mortality. Thus, we report only 6- and 8-days larval weights for that experiment.

Development and Survivorship differences Between Greenhouse (GH) and Field Grown (FD) Bermudagrasses. Source of grass and bermudagrass showed significant differences in larval and pupal weights and larval duration for all trials. Fall armyworm fed grasses grown in the greenhouse sustained higher larval and pupal weights and had shorter larval development periods than larvae fed the same grasses grown in the field with the exception 'Tifton 292' in trial 1 (Tables 1 and 2). Fall armyworm fed GH 'Coastal', 'Grazer', and 'OSU 71 X 6-7' weighed more than those fed FD 'Coastal', 'Grazer', and 'OSU 71 X 6-7' at 6-, 8-, and 10-days (Table 1). However, larvae fed FD 'Tifton 292' were 11, 44, and 88 mg heavier than those fed GH 'Tifton 292' at 6-, 8- and 10-days, respectively.

The pupal weights of FAW fed GH 'Coastal' (177 mg) were higher than FD 'Coastal' (144 mg) (Table 2). Pupae of larvae that were fed GH

Table 1. Larval weights of *S. frugiperda* feeding on bermudagrasses grown in the field (FD) and greenhouse (GH) (Trial 1: 13 June - 26 July 1986).

Bermuda-	6D wt (mg)		8D wt (mg)		10D wt (mg)	
grass	FD	GH	FD	GH	FD	GH
'Coastal'	15.7 bB	31.1 aA	57.3 bB	140.8 bA	148.3 bB	360.9 bA
'Grazer'	22.9 aA	34.8 aA	101.8 aB	165.2 aA	248.3 aB	428.3 aA
'OSU 71 X 6-7'	16.3 bB	23.1 bA	60.9 bB	99.8 cA	167.7 bB	249.1 cA
'Tifton 292'	23.9 aA	12.9 cB	101.7 aA	57.7 dB	234.6 aA	147.0 dB

Means within column followed by the same lowercase letter or means within row by date followed by the same uppercase letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test and t-test, respectively).

Table 2. Pupal weights, larval and pupal duration, and survivorship of *S. frugiperda* feeding on bermudagrasses grown in the field (FD) and greenhouse (GH) (Trial 1: 13 June - 26 July 1986).

Bermuda-grass	Pupal wt (mg)		Larval duration		Pupal duration		% Survivorship	
	FD	GH	FD	GH	FD	GH	FD	GH
'Coastal'	144.3 bcB	177.3 bA	15.6 aA	13.1 cB	8.2 aA	8.2 aA	88 aA	96 aA
'Grazer'	151.6 bB	203.1 aA	14.4 bA	12.9 cB	8.1 aA	7.7 bA	100 aA	88 aA
'OSU 71 X 6-7'	134.9 cB	172.9 bcA	15.4 aA	13.8 bB	8.3 aA	8.6 aA	92 aA	72 aA
'Tifton 292'	167.1 aA	165.4 cA	14.3 bB	15.4 aA	8.2 aA	8.5 aA	88 aA	76 aA

Means within column followed by the same lowercase letter or means within row followed by the same uppercase letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test and t-test, respectively).

'Grazer' and 'OSU 71 X 6-7' weighed 52 and 38 mg more than those fed FD 'Grazer' and 'OSU 71 X 6-7', respectively. For larvae fed FD and GH 'Tifton 292', pupal weights were not significantly different. Larvae fed GH grown bermudagrasses developed more rapidly as indicated by a shorter larval duration period. Larvae fed GH 'Coastal', 'Grazer', and 'OSU 71 X 6-7' showed a decreased larval development by 2.5, 1.5, and 1.6 days than those larvae fed the same FD grown bermudagrasses, respectively. However, larval development for FAW feeding on FD 'Tifton 292' was 1.1 day shorter than larvae fed GH 'Tifton 292'. Pupal duration and percent survival to the adult stage were not significantly influenced by source of grass. Survivorship was not influenced by source of grass; however larvae fed GH 'Grazer', 'OSU 71 X 6-7', and 'Tifton 292' had 12, 20, and 12% lower survival to adult than FD 'Grazer', 'OSU 71 X 6-7', and 'Tifton 292', respectively, though not significant.

Weights of FAW larvae for trial 2 are shown in Table 3. Comparison of 6- and 8-day larval weights indicated that FAW reared on GH 'Coastal' weighed more than FD grown 'Coastal'. Larvae were also heavier at 6- and 8-days when fed on GH 'Grazer' and 'Tifton 292' than larvae fed the same bermudagrasses grown in the field. Comparisons could not be drawn between FD and GH 'OSU 71 X 6-7' because none of the larvae survived on the FD grown plants (Table 4).

In trial 3, a significant interaction ($P < 0.05$) between bermudagrass and source of grass was detected at 6-, 8-, 10-day larval weights (Table 5) and larval development (Table 6). The 6-, 8-, and 10-day weights of larvae fed GH 'Coastal' were heavier than larvae fed FD 'Coastal'. Fall armyworm fed GH 'Grazer', 'OSU 71 X 6-7', and 'Tifton 292' weighed more than larvae fed FD 'Grazer', 'OSU 71 X 6-7', and 'Tifton 292' during the same time period.

Table 3. Larval weights of S. frugiperda feeding on bermudagrasses grown in the field (FD) and greenhouse (GH) (Trial 2: 11 July - 19 August 1986).

Bermuda-grass	6D wt (mg)		8D wt (mg)		10D wt (mg)	
	FD	GH	FD	GH	FD	GH
'Coastal'	6.9 aB	28.9 aA	21.1 bB	126.1 aA	- [b]	317.6 a
'Grazer'	9.5 aA	29.5 aA	35.1 aB	129.1 aA	-	355.7 a
'OSU 71 X 6-7'	0 [a]	28.3 a	0	118.5 a	0	331.7 a
'Tifton 292'	10.2 aB	30.2 aA	42.8 aA	159.1 aA	-	341.5 a

Means within column followed by the same lowercase letter or means within row by date followed by the same uppercase letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test and t-test, respectively).

[a] No larvae survived.

[b] No data due to insecticide mortality.

Table 4. Pupal weights, larval and pupal duration, and survivorship of *S. frugiperda* feeding on bermudagrasses grown in the field (FD) and greenhouse (GH) (Trial 2: 11 July - 19 August 1986).

Bermuda-	Pupal wt (mg)		Larval duration		Pupal duration		% Survivorship	
grass	FD	GH	FD	GH	FD	GH	FD	GH
'Coastal'	-[a]	174.3 a	-	13.6 a	-	8.6 a	-	96 a
'Grazer'	-	171.6 a	-	12.9 c	-	7.9 b	-	88 a
'OSU 71 X 6-7'	0[b]	177.4 a	0	13.5 ab	0	8.1 b	0	84 a
'Tifton 292'	-	185.8 a	-	13.1 bc	-	8.3 ab	-	88 a

Means within column followed by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test).

[a] No data due to insecticide mortality.

[b] No larvae survived.

Table 5. Larval weights of *S. frugiperda* feeding on bermudagrasses grown in the field (FD) and greenhouse (GH) (Trial 3: 8 August - 23 September 1986).

Bermuda-	6D wt (mg)		8D wt (mg)		10D wt (mg)	
grass	FD	GH	FD	GH	FD	GH
'Coastal'	3.3 bcB	13.5 cA	9.3 cB	48.2 cA	24.1 cB	142.5 cA
'Grazer'	10.4 aB	34.6 aA	39.4 aB	145.8 aA	101.4 aB	332.8 aA
'OSU 71 X 6-7'	2.7 cB	20.7 bA	11.0 cB	72.7 bA	28.3 cB	192.5 bA
'Tifton 292'	6.1 bB	18.9 bcA	20.8 bB	75.9 bA	64.1 bB	169.9 bcA

Means within column followed by the same lowercase letter or means within row by date followed by the same uppercase letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test and t-test, respectively).

Pupal weights of FAW in trial 3 reared on GH grown grasses had higher weights than larvae reared on the same FD grown grasses (Table 6). The pupal weights were 35, 41, 27, and 33 mg heavier in GH 'Coastal', 'Grazer', 'OSU 71 X 6-7', and 'Tifton 292', respectively. Larvae fed these same bermudagrasses required 4.8, 3.5, 4.7 and 2.6 days less time to develop than larvae fed the same FD grown grass, respectively. Significant differences in pupal duration between larvae fed FD and GH grown grasses were not detected. Survivorship of larvae fed GH 'Coastal', 'Grazer', and 'OSU 71 X 6-7' was higher than on the same FD grown grasses, though not significant. However, larvae reared on GH 'Tifton 292' had significantly lower survivorship to the adult stage than larvae fed FD 'Tifton 292'.

Forage Quality. The quality of bermudagrasses grown in the greenhouse was significantly higher than that of FD grown grasses in all trials (Tables 7, 8, and 9). In trial 1 (Table 7), GH grown grass had less non-digestible fractions (% NDF, ADF, CELL) and higher CP and IVDDM. Field grown 'Coastal', 'Grazer', and 'OSU 71 X 6-7' had significantly higher NDF but lower CP and IVDDM. In addition, concentration of AIL was significantly higher in GH 'Coastal' than in FD 'Coastal'. Significant differences between FD and GH 'Tifton 292' in trial 1 were not detected.

In trial 2 (Table 8), NDF was higher in the FD 'Grazer', 'OSU 71 X 6-7', and 'Tifton 292' than the same grasses grown in the greenhouse. Significant differences were not observed for NDF and AIL concentrations between FD and GH 'Coastal'. The concentrations of AIL between FD and GH 'Grazer' were not significantly different. The ADF and CELL concentrations of all FD grown grasses and AIL concentration of

Table 6. Pupal weights, larval and pupal duration, and survivorship of *S. frugiperda* feeding on bermudagrasses grown in the field (FD) and greenhouse (GH) (Trial 3: 8 August - 23 September 1986).

Bermuda-	Pupal wt (mg)		Larval duration		Pupal duration		% Survivorship	
grass	FD	GH	FD	GH	FD	GH	FD	GH
'Coastal'	151.9 aB	186.5 abA	20.4 aA	15.6 aB	8.3 aA	8.4 aA	64 bA	68 bA
'Grazer'	157.0 aB	197.5 aA	17.0 bA	13.5 bB	8.9 aA	8.5 aA	92 aA	96 aA
'OSU 71 X 6- 7	150.2 aB	177.5 bA	19.7 aA	15.0 aB	8.9 aA	8.5 aA	52 bA	68 bA
'Tifton 292'	148.6 aB	181.5 bA	17.7 bA	15.1 aB	8.6 aA	8.5 aA	88 aA	56 bB

Means within column followed by the same lowercase letter or means within row followed by the same uppercase letter are not significantly different (P > 0.05; Duncan's [1955] multiple range test and t-test, respectively).

Table 7. Quality composition of bermudagrasses grown in the field (FD) and greenhouse (GH) (Trial 1: 13 June - 26 July 1986).

Bermuda-grass	NDF (%)		ADF (%)		CELL (%)		AIL (%)		CP (%)		IVDDM (%)	
	FD	GH	FD	GH	FD	GH	FD	GH	FD	GH	FD	GH
'Coastal'	74.2 aA	67.9 bcB	32.6 aA	24.9 bB	30.3 aA	24.6 bB	2.5 abB	2.9 aA	9.7 bB	18.3 aA	61.9 bB	64.8 bA
'Grazer'	72.0 abA	66.8 cB	31.1 aA	23.3 bB	28.6 aA	22.9 bB	1.7 cA	1.7 bA	12.5 aB	17.6 aA	65.9 aB	67.7 aA
'OSU 71 X 6-7'	73.9 aA	68.4 bB	31.7 aA	24.6 bB	28.6 aA	24.5 bB	2.3 bA	2.3 abA	9.8 bB	16.6 aA	62.6 bB	65.5 bA
'Tifton 292'	71.1 bA	71.8 aA	30.3 aA	28.8 aA	26.2 bA	28.1 aA	2.7 aA	2.7 aA	14.5 aB	18.7 aA	63.8 bA	65.5 bA

Means within column followed by the same lowercase letter or means within row followed by the same uppercase letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test and t-test, respectively). NDF, neutral detergent fiber; ADF, acid detergent fiber; CELL, cellulose; AIL, acid insoluble lignin; CP, crude protein; IVDDM, in vitro digestible dry matter.

Table 8. Quality composition of bermudagrasses grown in the field (FD) and greenhouse (GH) (Trial 2: 11 July - 19 August 1986).

Bermuda-grass	NDF (%)		ADF (%)		CELL (%)		AIL (%)		CP (%)		IVDDM (%)	
	FD	GH	FD	GH	FD	GH	FD	GH	FD	GH	FD	GH
'Coastal'	73.4 bA	72.1 aA	31.5 abA	27.4 aB	30.1 aA	26.8 aB	3.2 cA	2.9 aA	16.2 aA	8.1 dB	60.6 bA	58.8 cA
'Grazer'	73.9 bA	65.4 cA	30.7 bA	21.4 cB	27.7 bA	23.7 bB	2.3 dA	2.8 aA	12.3 cB	22.3 aA	62.2 aB	68.7 aA
'OSU 71 X 6-7'	75.9 aA	67.5 bB	32.9 aA	21.9 cB	28.9 abA	22.9 bB	3.7 bA	2.3 bB	12.1 cA	13.4 cA	58.4 cB	64.3 bA
'Tifton 292'	75.1 aA	68.2 bB	33.0 aA	25.7 bB	28.3 bA	25.8 aB	4.2 aA	2.7 abB	13.6 bB	17.4 bA	58.1 cB	64.2 bA

Means within column followed by the same lowercase letter or means within row followed by the same uppercase letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test and t-test, respectively). NDF, neutral detergent fiber; ADF, acid detergent fiber; CELL, cellulose; AIL, acid insoluble lignin; CP, crude protein; IVDDM, in vitro digestible dry matter.

Table 9. Quality composition of bermudagrasses grown in the field (FD) and greenhouse (GH) (Trial 3: 8 August - 23 September 1986).

Bermuda-grass	NDF (%)		ADF (%)		CELL (%)		AIL (%)		CP (%)		IVDDM (%)	
	FD	GH	FD	GH	FD	GH	FD	GH	FD	GH	FD	GH
'Coastal'	74.9 aA	71.0 aB	33.4 aA	28.2 aB	30.7 aA	26.4 aB	4.2 aA	2.8 bB	14.1 aA	10.5 bB	55.1 cB	60.4 bcA
'Grazer'	73.5 aA	71.2 aA	31.6 aA	29.4 aB	28.4 bB	28.6 aA	2.4 dA	2.3 cA	12.8 aB	14.6 aA	59.9 aB	65.6 aA
'OSU 71 X 6-7'	74.2 aA	72.0 aB	32.6 aA	28.2 aB	27.6 bcA	26.8 aA	3.8 bA	3.3 aB	13.7 aA	14.8 aA	57.4 bB	59.7 cA
'Tifton 292'	74.6 aA	71.3 aB	32.2 aA	29.1 aA	26.7 cA	26.3 aA	3.5 cA	3.3 aA	13.4 aA	15.2 aA	57.3 bB	61.2 bA

Means within column followed by the same lowercase letter or means within row followed by the same uppercase letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test and t-test, respectively). NDF, neutral detergent fiber; ADF, acid detergent fiber; CELL, cellulose; AIL, acid insoluble lignin; CP, crude protein; IVDDM, _in vitro_ digestible dry matter.

FD 'OSU 71 X 6-7' and 'Tifton 292' were higher than the same grasses grown in the GH. Crude protein in GH grown grasses was higher than in the same grasses grown in the FD, while IVDDM was higher in GH grown grasses. Percent CP and IVDDM were highest in GH 'Grazer'.

In trial 3 (Table 9), FD grown bermudagrasses had a higher concentration of NDF than GH grown grasses. The ADF, CELL, and AIL concentrations of FD grown bermudagrasses, except concentration of CELL in 'Grazer', were also higher than GH grown grasses. The concentration of CP in GH grown grasses was higher than FD grown grasses, though not significant and with the exception of GH 'Coastal'. The % IVDDM in GH grown grasses was significantly higher than in FD grown grasses.

Responses of Fall Armyworm to Within Source (GH or FD) of Bermudagrass. Larvae fed FD 'Grazer' and 'Tifton 292' had significantly higher 6-, 8-, and 10-day larval weights than larvae fed FD 'Coastal' and 'OSU 71 X 6-7' in trial 1 (Table 1). The larvae fed GH 'Grazer' and 'Coastal' had significantly higher 6-, 8-, and 10-day larval weights than larvae fed GH 'OSU 71 X 6-7' and 'Tifton 292'.

The pupal weights of larvae fed FD 'Tifton 292' was significantly higher than the other grasses (Table 2). Larvae fed FD 'Coastal' and 'OSU 71 X 6-7' had significantly longer larval development periods than those fed FD 'Grazer' and 'Tifton 292'. The larvae fed GH 'Grazer' had significantly higher pupal weights than the other grasses. Larvae fed GH 'Grazer' and 'Coastal' had significantly shorter larval development periods than larvae fed GH 'OSU 71 X 6-7' and 'Tifton 292'. Pupal duration periods were not significantly different among the FD grown grasses tested. Larvae reared on GH 'Grazer' had significantly shorter pupal duration period than other grasses. Survivorship were not significantly different among the grasses whether they were grown in the field or greenhouse.

In trial 2, larvae fed FD 'Grazer' and 'Tifton 292' had higher 6-, 8-day larval weights than FD 'Coastal' (Table 3). Larval weights at 6-, 8-, and 10-day were not significantly different among the GH grown grasses tested. Larvae reared on GH 'Grazer' had lower pupal weights and shorter larval and pupal development periods (Table 4). However, survivorship was not significantly different among the GH grown grasses.

Fall armyworm reared on FD 'Grazer' had significantly higher 6-, 8-, and 10-day larval weights than the other grasses in trial 3 (Table 5). The same results were observed when larvae were fed GH 'Grazer'. Pupal weights were not significantly different among the FD grown grasses tested (Table 6). Longer larval development periods and lower survivorship were observed when larvae were fed FD 'Coastal' and 'OSU 71 X 6-7' than FD 'Grazer' and 'Tifton 292'. Fall armyworm fed FD 'Coastal' had a shorter period for pupal development than the other FD grasses. Larvae reared on GH 'Grazer' had higher pupal weights than those fed 'OSU 71 X 6-7' and 'Tifton 292'. They also had a significantly shorter larval development period and higher survivroship than larvae fed 'Coastal', 'OSU 71 X 6-7', and 'Tifton 292'. Pupal duration periods were not significantly different among the GH grown grasses tested.

Forage Quality. Field grown 'Tifton 292' had signifiacntly lower NDF and CELL concentrations than the other grasses in trial 1 (Table 7). The reverse was observed for GH 'Tifton 292'. Field and GH 'Grazer' had lower AIL concentrations than the other grasses tested. The FD 'Grazer' and 'Tifton 292' had higher CP concentrations, while the FD 'Grazer' had highest % IVDDM. Significant differences were not observed in CP concentrations in GH grown grasses. However, GH 'Grazer' had the highest percentage of IVDDM than the other grasses (Table 7).

Among those grasses tested, NDF concentrations of FD 'Coastal' and 'Grazer' was significantly lower than the other grasses in trial 2 (Table 8). The FD 'Grazer' also had lower concentrations of ADF, CELL, and AIL than the other grasses. Field grown 'Coastal' had the highest concentration of CP, while FD 'Grazer' had highest % IVDDM. The GH 'Coastal' had higher NDF, ADF, CELL, and AIL concentrations but lower % CP and IVDDM than the other grasses.

In trial 3, FD 'Grazer' had the lowest concentrations of NDF, ADF, AIL, and CP but a higher % IVDDM than other grasses (Table 9). The NDF, ADF, and CELL concentrations of GH grown grasses were not significantly different. The AIL concentrations of 'Grazer' were significantly lower than the other grasses. The GH 'Tifton 292' had significantly higher CP concentrations, while GH 'Grazer' had a significantly higher % IVDDM.

DISCUSSION

In general, protein and carbohydrate requirements of immature insects are more uniform than those observed for adult insects. Protein is needed for normal growth and development or, in the case of adults, egg production (House 1965, Scriber & Slansky 1981). Soo Hoo & Fraenkel (1966) reported that higher protein (30%) in plant leaves enhanced the acceptibility and growth of larvae of the southern armyworm, *Spodoptera eridania* (Cramer). In addition, many researchers include water as a nutrient because of its role in the growth and development of leaf-eating insects (Reese & Beck 1978, Scriber 1977). Thus, an insect's ability to develop well on a food source depends on the acceptibility and digestibility of the food source.

Crude protein has long been recognized as an indicator of forage quality for ruminants (Montgomery et al. 1979) and one of the best predictors of digestibility for tropical species (Barton et al. 1976). In vitro digestible dry matter is a good measure of forage digestibility (Montgomery et al. 1979). Quisenberry & Wilson (1985) reported that as cell wall content or NDF concentration in bermudagrass increased, the % IVDDM decreased. Rainwater (1975) found that the more digestible varieties seemed to have the lowest in NDF concentration. Coelho (1982) reported % CP and IVDMD were the best predictors for voluntary dry matter intake (DMI) in animal and in vivo dry matter digestibility (DMD). Utley et al. (1974) reported that % CP and IVDMD were correlated with average daily gain in cattle.

Protein concentration in 'Coastal' bermudagrass can be influenced by the level of nitrogen fertilization and age of plant regrowth. Concentration of CP increases as the level of nitrogen fertilization increases and decreases with plant senescence (Prine & Burton 1956, Lynch et al. 1984). High nitrogen fertilization levels also promote higher digestibility (% IVDMD), but reduced digestibility is observed in plants as they age (Monson & Burton 1982, Lynch 1984). Lynch et al. (1986) related forage quality of 'Coastal' bermudagrass to biological parameters of FAW and found that % CP and IVDMD were highly correlated with larval weight gain. Lynch et al. (1983) also showed that varieties such as 'Tifton 67', 'Tifton 68', and 'Tifton 84' with high % CP and IVDMD were more susceptible to FAW feeding. 'Tifton 68', which had the highest average % CP and IVDMD among the hybrids tested by Monson &

Burton (1982), was the most susceptible to FAW feeding (Lynch et al. 1983). Quisenberry & Wilson (1985) also found that larvae fed bermudagrass with high % CP and IVDDM had decreased rates of consumption and maintenance requirements which resulted in increased efficiency of ingested and digested food.

In this study, FAW larval fed field (FD) grown bermudagrasses from June to September had reduced larval weight and increased duration of development than those larvae fed the same grasses grown in the greenhouse. During all trials, 6- and 8-day weights of larvae fed FD 'Coastal' were 2 and 2.5-fold, respectively, less than larvae fed GH 'Coastal' (Tables 1, 3, 5). Survivorship of FAW reared on FD grown grasses (trial 1) was higher than those fed grasses grown in the GH, except 'Coastal'. Larvae reared on FD grasses had lower weights and a longer larval development period. Larval weights and survivorship of FAW fed FD grasses also were lower and larval duration longer in trial 3 than in trial 1 since the quality of FD grown grasses declined. The FD grasses had higher non-digestible fractions (% NDF, AIL) over time (Tables 7, 8, and 9) and could not be digested as well by FAW. Thus, growth and development of larvae fed FD grasses were suppressed. Beside these non-digestible fractions, FD grown grasses also had a lower % IVDDM over time. Field grown grasses showed differences in % IVDDM between trials 1 and 2 and trials 2 and 3. Differences in % IVDDM among grasses within trials ranged from 2-3% (trial 1), 2-7% (trial 2), and 3-6% (trial 3).

Weights and duration of development of larvae reared on FD 'Coastal' in this study were similar to results reported by Lynch (1984). In their study, larvae fed FD 'Coastal' in June had 10 day larval and pupal weights of 137 and 163 mg, while larval and pupal weights in our study were 148 and 144 mg, respectively (Tables 2 and 3). Larval duration was 16 days in both studies. In August, 10 day larval and pupal weights were 59 and 135 mg in the Lynch (1984) study as compared with 24 and 152 mg in our study (Tables 5 and 6), respectively. A larval duration of 20 days was observed in both studies. In contrast, the GH 'Coastal' fed to FAW during trial 3 showed 3-fold higher larval weights (at 6-, 8-, and 10 days) and 54 mg higher pupal weights (Tables 5, 6) than those observed in a similar study using GH 'Coastal' (Lynch et al. 1983). Larval duration was also 3 days shorter in our study. Lynch et al. (1983) also reported 100% mortality of larvae feeding on GH 'Tifton 292'. In our study, larval mortality was 22% on GH 'Tifton 292' and 44% on FD 'Tifton 292'. Jamjanya (1987) and Pashley et al. (1987) reported only a 24% mortality of larvae reared on GH 'Tifton 292'. Pashley (1986) found that FAW collected from bermudagrass/rice were genetically different from FAW collected from corn and concluded that there were two distinct FAW strains. Pashley et al. (1987) also reported that the bermudagrass/rice FAW strain developed better on 'Tifton 292' than did larvae of the corn FAW strain. In our study, the bermudagrass/rice FAW strain was used, while Leuck et al. (1968) and Lynch et al. (1983) used the corn FAW strain in their studies. Because these strains are host specific, it can be concluded that 'Tifton 292' grown either under field or greenhouse conditions was not resistant to FAW as previously reported by Leuck et al. (1968) and Lynch et al. (1983).

Numerous investigators have documented the fluctuation of forage quality over the growing season. Brown et al. (1976) found that the percent digestible dry matter of 'Coastal' bermudagrass harvested at 4 week intervals increased in June, July and declined in August, September, and October. Monson & Burton (1982) reported that percentage of IVDDM in 'Coastal' decreased during the growing season. Joliff et al. (1979) found a monthly variation in quality (% CP, ADF, IVDDM) of 'Coastal' and 'Coastcross-1'. Montgomery et al. (1979) reported that CP concentration was highest on May 1 and September 17. Thus, these data support the results of our study in that the quality of the FD grown bermudagrasses declined from June to September.

In the greenhouse, the quality of grass also declined over time but the decline occurred in an inconsistent pattern. A planthopper infestation on 'Coastal', 'OSU 71 X 6-7', and 'Tifton 292' was a major problem during trial 3 and appeared to have suppressed the quality of these grasses. The quality of the GH grasses in trial 2 was similar to trial 1 except 'Coastal' which had higher fiber and lower % CP and IVDDM. In trial 3, the quality of all grasses declined because fiber content increased (high NDF) which resulted in a lower % IVDDM (Table 9).

The relationships between temperature and light on the quality of tropical and temperate grasses have been investigated by numerous researchers. Henderson & Robinson (1982) concluded that temperature had a significant effect on forage digestibility. In vitro true digestibility of bermudagrass, bahiagrass, and dallisgrass decreased as temperature increased. In our study, the FD grown bermudagrasses were exposed to higher ambient temperatures and lower moisture, thus, the plants matured and the quality declined more rapidly than grasses grown in the GH where the environment could be more closely controlled. The low quality of FD grass, high fiber and low % CP, IVDDM, and water, resulted in forages that were less acceptable and digestible to FAW than grasses grown in the GH.

Responses of FAW larvae to within source (GH or FD) of bermudagrass demonstrated that larvae fed either GH or FD grown 'Grazer' developed better in all trials than larvae reared on the other bermudagrasses. This was indicated by higher larval and pupal weights and shorter larval development periods. 'Grazer' has been ranked as a susceptible variety to FAW feeding (Jamjanya 1987). It is a higher quality bermudagrass as indicated by lower non-digestible fractions (% NDF, AIL) and higher % IVDDM than the other bermudagrasses evaluated. Thus, 'Grazer' enhances FAW development and survivorship. Lynch et al. (1983) and Lynch (1984) also found FAW showed different developmental responses when reared on different bermudagrasses.

Most of the previous evaluations of bermudagrasses for resistance to FAW utilized GH grown plants (Leuck et al. 1968, Lynch et al. 1983, Quisenberry & Wilson 1985). However, the results of this study indicate that data from greenhouse experiments alone should not be used to delineate the level of FAW resistance in bermudagrass. Findings of studies conducted in the greenhouse should be confirmed with field studies. Time of year studies should be considered since the quality of bermudagrass fluctuates throughout the season. In the field, the environment from July to September had an adverse effect on the digestibility of bermudagrass and impacted growth and development of FAW.

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CHAPTER III

IMPACT OF FALL ARMYWORM (LEPIDOPTERA: NOCTUIDAE) ON THE QUALITY AND YIELD OF 'COASTAL' AND 'ALICIA' BERMUDAGRASSES

This Chapter is Written in the Style of

Journal of Economic Entomology

ABSTRACT

The impact of fall armyworm (FAW), Spodoptera frugiperda (J. E. Smith) feeding on the quality and yield of bermudagrass, Cynodon dactylon (L.) Pers., var. 'Coastal' and 'Alicia', was determined. Yield losses of 'Coastal' and 'Alicia' ranged from 0.5 to 1.1 and from 0.3 to 0.9 metric ton per ha, respectively, when artificially infested with populaton densities of 1.1 to 9.9 larvae per 0.1 m^2. Fall armyworm feeding also resulted in lower yields of digestible dry matter (245 kg/ha) and crude protein (72 kg/ha) in 'Coastal'. The economic injury level of 8 FAW larvae per 0.1 m^2 for 'Coastal' was calculated using a hay price of $54 per metric ton and cost of control of $6.74 per ha. Economic threshold of 4 larvae per 0.1 m^2 were suggested for 'Coastal'. 'Alicia' exhibited more resistance to FAW feeding than 'Coastal' as indicated by lower damage ratings and losses of quality and yield.

INTRODUCTION

The fall armyworm (FAW), Spodoptera frugiperda (J. E. Smith) is one member of a complex of defoliating insects which devastate many food crops and grasses in the southeast and central United States (Luginbill 1928). Unlike most other insects in the temperate region, the FAW exhibits no diapause and is thought to overwinter in south Florida and Texas where hosts are continually available and temperatures are below 10°C rarely occur (Luginbill 1928). Luginbill (1928) noted numerous reports of FAW outbreaks in the United States from 1856 to 1928. Most recently, the worst FAW infestations were in the southeastern United States and along the Atlantic Coast during a period from 1975 to 1977 (Sparks 1979). The economic losses on all crops were estimated at $61.2, $31.9 and $297.2 million in 1975, 1976, and 1977, respectively (Hunt 1978, Sparks 1979). The loss of hay pasture alone was estimated at $59 million in Georgia in 1977 (Todd & Suber 1980).

Lynch (1984) reported that FAW feeding on bermudagrass, Cynodon dactylon (L.) Pers., resulted in a greater yield reduction than that observed for any other pest on this crop. As a result of the plant-stress induced by FAW feeding on bermudagrass, researchers have attempted to establish economic injury levels (EIL) and economic thresholds (ET) for this pest because of the potential use of such data as decision making tool for better crop management (Poston et al. 1983, Buntin 1986). Martin et al. (1980) used data from laboratory leaf consumption studies were initially used to project an EIL for FAW feeding on 'Coastal' bermudagrass of 5 larvae per 0.1 m^2 based on these data.

Martin et al. (1980) also used FAW field population data, hay prices and control costs to recommended an EIL for 'Coastal' of 2 to 4 larvae per 0.1 m^2. Alvarado et al. (1983) reported an EIL of 0.8 third and fourth instar larvae per m^2 and 1.5 fifth and sixth instar larvae per m^2 for 'Alicia'. They also correlated these figures to 0.7 and 0.9 larvae per sweep, respectively. Furthermore, Suber et al. (1979) proposed an action threshold of 2 larvae (0.95 cm in size) per 0.1 m^2.

Although it is known that FAW larvae affect bermudagrass yield and attempts have been made to quantify economic injury levels (Martin et al. 1980, Alvarado et al. 1983), research is still needed to clarify the relationship between FAW density and bermudagrass yield and to measure the response of forage quality to FAW defoliation (Buntin 1986). Therefore, this study was conducted to determine the impact of varying FAW larval densities on forage quality and yield of 'Coastal' and 'Alicia' bermudagrasses and to utilize these data for the establishment of economic injury levels and economic thresholds.

MATERIALS AND METHODS

Field experiments were conducted during 1983 and 1984 in established stands of 'Coastal' and 'Alicia' bermudagrasses at the St. Gabriel Experiment Station in Iberville Parish, La. A separate split-plot design, with main plots of FAW population gradients, was arranged in a randomized complete block design with five replications for each bermudagrass. The subplots consisted of four plant sampling periods with each plot sampled at 6 and 7 day intervals postinfestation in 1983 and 1984, respectively. Plot size was 2 by 3 m or $6m^2$.

The study in 1983 was composed of two FAW infestation periods. The first trial was conducted from 22 July to 15 August and the second began on 23 August and ended on 16 September. In 1984, there was only one infestation period, from 10 August to 7 September.

One week prior to FAW infestation, grass was clipped to ca. 7 cm height and fertilized with ammonium nitrate (equivalent to 227 kg/ha). Plots were also treated at this time with methyl parathion (1.1 kg a.i./ha) to establish insect-free plots. Metal barriers (23 cm) were implanted to a depth of 10 cm around each plot. Tanglefoot® was applied in a band (8 cm) along the top interior of each barrier to prevent insect dispersal. The control plots were treated with carbaryl (Sevin XLR; 0.6 kg a.i./ha) to maintain an insect-free environment. After a 2 week feeding period, carbaryl was applied once to plots to remove all released FAW in order to ascertain bermudagrass recovery potential.

Plots were infested with fourth and fifth instar larvae at densities of 0, 1.1, 2.2, 3.3, 6.6 and 9.9 larvae per 0.1 m^2. Larvae were reared in compartment trays (15 by 15 by 1.5 cm) containing 230 ml of modified pinto bean diet, according to the procedures described by Perkins (1979). Trays were infested with 200 neonate larvae and maintained in a growth chamber at 26 ± 1 °C, 14-h light cycle, and > 50% RH. The number of larvae per tray was counted 1 day prior to release into the barrier plots.

Quantitative measurements of bermudagrass development were taken before harvest. In 1983, one 0.06 m^2 grass sample was taken in each plot at four consecutive 6 day intervals postinfestation. In 1984, the number of samples per plot was changed to four, 0.015 m^2 subsamples taken at 7 day intervals postinfestation. Plant height was estimated by sampling 10 plants per plot and measuring the extended leaf height. In 1984, FAW feeding damage was determined for each sample by using a 0 to 10 damage rating scale (0 = no damage, 10 = 90-100% defoliation) according to Wilde & Apostol in 1984 (1983). All plants within the sample area were clipped, placed in separate bags, and brought to the laboratory for further analyses.

Treatment samples were weighed and a subsample taken to determine leaf area, leaves per stem, and dry weight. A portable leaf area meter (Li-Cor Model LI-3000) was used to determine the leaf area of 20 leaves per plot. The leaves were dried at 60°C and used to determine leaf weight. Ten stems from each subsample were randomly selected to determine the number of leaves per stem. In 1984, the total number of leaves was also counted to calculate leaf area index. Leaf area subsamples were oven-dried at 60°C for 2 days and dry weight yield recorded. The leaf area index, an indicator of photosynthetic capacity, was calculated by dividing leaf area by land area.

Measurements of plant quality and yield were made after 24 and 28 days of regrowth in 1983 and 1984, respectively, by harvesting 0.5 m^2 area from each plot. Wet weight was recorded and total DM yield was calculated based on a percent dry weight basis of subsamples. Forage quality was analyzed from the DM yield samples. Subsamples were oven dried at 60°C and ground in a Wiley mill to pass through a 1-mm screen. Quality analyses of bermudagrass tissue were performed using near infrared (NIF) spectroscopy calibrated to the respective test. Neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose (CELL), and acid insoluble lignin (AIL) were determined as described by Goering & Van Soest (1970). Crude protein (CP) was analyzed by the improved

Kjeldahl method (Association of Official Agricultural Chemists 1980). *In vitro* digestible dry matter (IVDDM) was determined by the modified Van Soest procedure (Nelson et al. 1976). Quality and DM measurements were combined to caculate yield of CP and digestible dry matter (DDM).

Data were subjected to analysis of variance using the SAS GLM procedure (Freund & Littell 1981). Significant treatment means were separated using Duncan's (1955) multiple range test. Unless otherwise stated, significant differences imply a ≤ 0.05 probability level. *S. frugiperda* density and yield loss from 1983 and 1984 were combined and subjected to regression analyses. Yield loss (DM) per ha (y), which was calculated as the difference in loss between the infested and control plots, as regressed on larval density (x) per 0.1 m^2 and the equation forced through the origin. The following equation was used to predict yield loss: $y = bx$, where y = yield loss, b = the slope, and x = number of larvae per 0.1 m^2. Equations to estimate yield loss and the economic injury level of FAW on 'Coastal' bermudagrass were calculated using fluctuating hay prices. Costs, including sprayer and tractor operation, labor, and cost of insecticide, were defined and control costs were calculated. From these data, economic injury levels (the point at which dollars losses equal control cost in the same unit area) were established.

RESULTS

S. frugiperda feeding damage on 'Coastal' and 'Alicia' bermudagrasses, as indicated by a damage rating index, became more pronounced as the number of larvae per plot increased (Table 1). Feeding evidence

Table 1. S. frugiperda feeding damage on 'Coastal' and 'Alicia' bermudagrasses as indicated by a damage rating index, 1984.[a]

Larvae per 0.1 m^2	Days after infestion 7	14	21
'Coastal'			
0	0 d	0 c	0 c
1.1	1.6 cd	1.7 bc	1.1 b
2.2	1.8 cd	2.0 b	0.9 b
3.3	2.5 bc	2.3 b	0.9 b
6.6	4.2 b	3.3 b	1.0 b
9.9	7.2 a	5.6 a	2.8 a
'Alicia'			
0	0 d	0 d	0 b
1.1	1.1 cd	1.5 cd	0.5 b
2.2	1.6 bc	2.4 bc	1.3 a
3.3	2.5 b	2.6 bc	1.3 a
6.6	4.0 a	3.9 ab	1.5 a
9.9	5.1 a	4.8 a	1.8 a

Means within column by variety followed by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test).

[a] Damage Rating Index: 0 = no defoliation to 10 = 90-100% defoliation.

was reflected by wholly or partly missing leaves. Densities of 6.6 and 9.9 larvae per 0.1 m^2 caused the most prevalent damage at 7 days in the 'Coastal' and 'Alicia' plots. The damage ratings for 'Coastal' and 'Alicia' plots for densities of 3.3, 6.6, and 9.9 larvae per 0.1 m^2 were significantly higher than the control. In 'Alicia' plots, feeding at a density of 2.2 larvae per 0.1 m^2 also caused a significantly higher damage rating than the control. At 14 and 21 days postinfestation, damage rating in 'Coastal' and 'Alicia' plots followed the same pattern as observed at 7 days; however, the damage ratings were lower for corresponding density levels as the number of days postinfestation increased.

Leaf area in 'Coastal' was reduced by all larval density levels at 12 days postinfestation during the first trial in 1983 (Table 2). During the second trial in 1983, leaf area at 6 and 12 days was significantly less in plots with S. frugiperda densities of 9.9 larvae per 0.1 m^2 than in control plots, while leaf area at 24 days at densities of 2.2, 3.3, 6.6, and 9.9 larvae per 0.1 m^2 was less than that in control plots. In 1984, leaf area was only significantly less than the control only at 7 days postinfestation for FAW densities of 1.1, 2.2, 3.3, and 9.9 larvae per 0.1 m^2.

Leaf area was significantly affected in the 'Alicia' plots only during the first infestation period in 1983 (Table 3). Leaf area was reduced 12 days postinfestation in plots with densities of 3.3, 6.6, and 9.9 larvae per 0.1 m^2 compared to the control.

The leaf area index of 'Coastal' and 'Alicia' as affected by FAW feeding is given in the Appendix, Table 2. The only significant impact on leaf area index was observed 7 days postinfestation in 'Coastal' at

Table 2. Leaf area (cm^2) of 'Coastal' bermudagrass as affected by *S. frugiperda* feeding.

	Larvae per 0.1 m^2	Days after infestation[a] 6(7)	12(14)	18(21)	24(28)
Trial 1-1983					
	0	34.6 a	42.4 a	31.4 a	43.7 a
	1.1	31.5 a	30.5 b	28.1 a	45.9 a
	2.2	29.8 a	22.4 c	29.6 a	51.4 a
	3.3	29.0 a	26.5 bc	30.4 a	50.9 a
	6.6	29.3 a	25.8 bc	28.4 a	48.7 a
	9.9	31.4 a	25.1 bc	27.4 a	52.5 a
Trial 2-1983					
	0	33.1 a	44.1 a	49.8 a	61.7 a
	1.1	31.1 ab	36.5 ab	47.9 a	53.2 ab
	2.2	25.6 bc	39.5 ab	42.9 a	49.7 b
	3.3	26.7 abc	38.4 ab	44.8 a	46.5 b
	6.6	26.2 abc	35.4 ab	44.9 a	49.2 b
	9.9	23.1 c	31.9 b	39.9 a	42.3 b
Trial 1-1984					
	0	31.2 a	30.6 a	24.8 a	36.1 a
	1.1	22.9 b	27.8 a	28.3 a	29.4 a
	2.2	22.3 b	27.2 a	31.5 a	35.2 a
	3.3	21.8 b	21.3 a	26.7 a	33.1 a
	6.6	24.4 ab	21.4 a	27.1 a	28.8 a
	9.9	16.7 b	26.6 a	26.4 a	29.3 a

Means within column by trial followed by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test).

[a] Sampling periods 6, 12, 18, 24 days after infestation in 1983 during two trials; 7, 14, 21, 28 days in 1984.

Table 3. Leaf area (cm^2) of 'Alicia' bermudagrass as affected by *S. frugiperda* feeding.

	Larvae per 0.1 m^2	Days after infestation[a] 6(7)	12(14)	18(21)	24(28)
Trial 1-1983					
	0	13.9 a	19.3 a	17.7 a	27.8 a
	1.1	12.4 a	15.0 abc	17.6 a	28.9 a
	2.2	10.9 a	17.3 ab	16.1 a	26.0 a
	3.3	11.6 a	12.9 bc	14.0 a	27.0 a
	6.6	10.5 a	13.7 bc	17.6 a	32.9 a
	9.9	10.8 a	11.7 c	15.2 a	32.7 a
Trial 2-1983					
	0	19.2 a	29.7 a	46.9 a	36.0 a
	1.1	21.7 a	27.4 a	38.0 a	37.1 a
	2.2	18.3 a	23.8 a	41.5 a	37.3 a
	3.3	19.1 a	26.7 a	36.3 a	31.9 a
	6.6	16.1 a	24.5 a	38.6 a	32.5 a
	9.9	14.2 a	22.9 a	36.2 a	30.5 a
Trial 1-1984					
	0	17.3 a	19.7 a	23.8 a	18.9 a
	1.1	16.1 a	19.1 a	18.9 a	20.3 a
	2.2	16.5 a	17.6 a	20.5 a	19.7 a
	3.3	14.0 a	13.4 a	19.7 a	21.3 a
	6.6	12.9 a	17.0 a	19.4 a	20.3 a
	9.9	14.7 a	18.3 a	19.5 a	21.3 a

Means within column by trial followed by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test).

[a] Sampling periods 6, 12, 18, 24 days after infestation in 1983 during two trials; 7, 14, 21, 28 days in 1984.

FAW densities of 2.2, 3.3, 6.6, and 9.9 larvae per 0.1 m^2. The number of leaves per stem of 'Coastal' (Appendix, Table 3) and 'Alicia' (Appendix, Table 4) were not affected by FAW feeding.

Plant height was reduced in 'Coastal' plots 12 days postinfestation during the first trial in 1983 only (Table 4). Fall armyworm feeding reduced plant height in plots with densities of 2.2, 3.3, 6.6, and 9.9 larvae per 0.1 m^2 compared to the control plot. In 1984, plant height was significantly lower in the 'Coastal' plots at 7 and 14 days postinfestation.

Densities of 2.2, 3.3, 6.6, and 9.9 larvae per 0.1 m^2 reduced plant height in 'Coastal' plots at 7 and 14 days. Densities of 2.2, 6.6, and 9.9 larvae per 0.1 m^2 decreased plant height in 'Alicia' plots (Table 5). In 1984, plant height was reduced in 'Alicia' at 7 days postinfestation.

Weekly DM yields of 'Coastal' were affected by FAW feeding during the first trial in 1983 (Appendix, Table 5). At 6 days all yields in the infested plots were lower than the control, but only the yields of plots infested with 6.6 larvae per 0.1 m^2 were significantly lower. Densities of 1.1, 2.2, 3.3, 6.6, and 9.9 larvae per 0.1 m^2 reduced yields 12 days postinfestation, while all FAW densities significantly reduced yields at 18 days. At 24 days, yields were also significantly lower by FAW levels of 2.2, 3.3, and 6.6 larvae per 0.1 m^2. Weekly yields were not significantly affected by FAW feeding during the second trial in 1983. In 1984, only the dry matter yields of plots infested with 3.3, 6.6, and 9.9 larvae per 0.1 m^2 at 7 days postinfestation were lower than the control. Weekly DM yields of 'Alicia' were not significantly affected by FAW feeding in 1983 or 1984 (Appendix, Table 6).

Table 4. Height (cm) of 'Coastal' bermudagrass as affected by *S. frugiperda* feeding.

	Larvae per 0.1 m^2	Days after infestation[a] 6(7)	12(14)	18(21)	24(28)
Trial 1-1983					
	0	23.7 a	28.2 a	29.2 a	42.2 a
	1.1	19.3 a	23.6 ab	28.4 a	41.3 a
	2.2	21.6 a	21.6 b	23.9 a	40.9 a
	3.3	18.7 a	22.0 b	27.5 a	39.7 a
	6.6	20.3 a	21.1 b	27.0 a	41.1 a
	9.9	19.9 a	19.7 b	27.5 a	42.0 a
Trial 2-1983					
	0	23.2 a	31.2 a	39.7 a	46.4 a
	1.1	21.7 a	28.1 a	36.3 a	45.9 a
	2.2	21.8 a	29.2 a	35.6 a	41.2 a
	3.3	21.8 a	28.8 a	35.2 a	43.1 a
	6.6	20.3 a	28.5 a	34.9 a	44.3 a
	9.9	20.7 a	27.4 a	32.0 a	43.2 a
Trial 1-1984					
	0	25.7 a	32.4 a	34.9 a	40.9 a
	1.1	23.5 ab	30.0 ab	36.9 a	40.3 a
	2.2	22.0 b	28.6 bc	36.8 a	40.6 a
	3.3	22.0 b	27.6 bc	32.2 a	38.8 a
	6.6	21.9 b	27.9 bc	33.4 a	38.6 a
	9.9	21.1 b	27.2 c	31.9 a	36.8 a

Means within column by trial followed by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test).

[a] Sampling periods 6, 12, 18, 24 days after infestation in 1983 during two trials; 7, 14, 21, 28 days in 1984.

Table 5. Height (cm) of 'Alicia' bermudagrass as affected by *S. frugiperda* feeding.

	Larvae per 0.1 m^2	Days after infestation[a]			
		6(7)	12(14)	18(21)	24(28)
Trial 1-1983					
	0	12.4 a	17.7 a	19.6 a	35.6 a
	1.1	14.1 a	15.8 a	20.5 a	34.5 a
	2.2	14.2 a	16.4 a	18.6 a	35.1 a
	3.3	12.9 a	15.0 a	18.6 a	34.0 a
	6.6	13.1 a	15.8 a	17.6 a	34.5 a
	9.9	12.9 a	14.9 a	16.5 a	35.4 a
Trial 2-1983					
	0	20.8 a	30.8 a	42.0 a	44.5 b
	1.1	23.8 a	29.1 a	45.8 a	51.4 a
	2.2	19.8 a	26.0 a	42.9 a	51.0 a
	3.3	21.6 a	30.1 a	47.1 a	46.9 ab
	6.6	23.7 a	29.2 a	46.2 a	43.6 b
	9.9	20.4 a	27.5 a	38.6 a	46.9 ab
Trial 1-1984					
	0	19.8 a	26.7 a	28.9 a	29.7 a
	1.1	19.6 a	24.3 a	29.3 a	33.8 a
	2.2	17.2 b	23.4 a	30.2 a	33.2 a
	3.3	17.7 ab	23.2 a	27.6 a	33.2 a
	6.6	17.2 b	23.5 a	27.5 a	31.9 a
	9.9	17.7 b	22.4 a	28.0 a	34.2 a

Means within column by trial followed by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test).

[a] Sampling periods 6, 12, 18, 24 days after infestation in 1983 during two trials; 7, 14, 21, 28 days in 1984.

During the first and second trials in 1983, DM yields of 'Coastal' were higher in the control plots than in infested plots and DM yields were significantly reduced in plots treated with 3.3, 6.6, and 9.9 larvae per 0.1 m^2 during both trials (Table 6). A density of 2.2 larvae per 0.1 m^2 also significantly reduced yield during the first trial. In 1984, total DM yields of 'Coastal' were lower in plots infested with 2.2, 3.3, 6.6, and 9.9 larvae per 0.1 m^2 than the control, but not at a significant level. Dry matter yields of 'Alicia' were not affected by any density level in 1983 or 1984 (Table 7).

Crude protein concentration of 'Coastal' with 3.3 larvae per 0.1 m^2 was significantly lower than the control plot during the first trial in 1983 (Table 6). Percent CP of 'Coastal' was not affected by any density level in the second trial. Percent IVDDM of all infested 'Coastal plots were significantly lower than the control plot during the first trial in 1983. Densities of 6.6 and 9.9 larvae per 0.1 m^2 significantly reduced % IVDDM of 'Coastal' during the second trial. Percent CP and IVDDM were not affected by any density level in 1984.

For 'Alicia', % CP in all infested plots were lower than the control plots during both trials in 1983, but differences were not significant (Table 7). In 1984, CP concentration of 'Alicia' with a density of 9.9 larvae per 0.1 m^2 was significantly higher than the control plot. Percent IVDDM of all infested 'Alicia' plots were significantly lower than the control plot during the first trial in 1983. In trial 2, densities of 1.1, 3.3, 6.6, and 9.9 larvae per 0.1 m^2 significantly reduced % IVDDM in 'Alicia' plots. Percent IVDDM was not significantly affected by FAW feeding in 1984.

Table 6. The effects of varying S. frugiperda densities on % CP and IVDDM and yields of DM, DDM and CP in 'Coastal' bermudagrass.

	Larvae per 0.1 m^2	DM Yield kg/ha	CP %	CP kg/ha	IVDDM %	IVDDM kg/ha DDM
Trial 1 1983						
	0	2329 a	17.2 a	409 a	55.5 a	1299 a
	1.1	2131 ab	15.9 ab	338 b	54.3 b	1155 ab
	2.2	1802 b	16.9 a	308 b	54.5 b	985 b
	3.3	1924 b	15.6 b	308 b	54.2 b	1048 b
	6.6	1875 b	16.8 ab	313 b	54.5 b	1017 b
	9.9	1816 b	16.1 ab	292 b	54.2 b	984 b
Trial 2 1983						
	0	4125 a	15.9 a	678 a	55.7 a	2307 a
	1.1	3661 ab	16.2 a	608 ab	55.1 a	2029 ab
	2.2	3684 ab	16.2 a	628 ab	55.2 a	2049 ab
	3.3	3540 bc	16.2 a	586 ab	55.3 a	1968 b
	6.6	3316 bc	16.4 a	563 ab	53.2 b	1776 bc
	9.9	3092 c	16.2 a	525 b	52.9 b	1649 c
Trial 1 1984[a]						
	0	2025 a	8.6 a	176 a	49.9 a	1012 a
	1.1	2025 a	8.3 a	168 a	48.9 a	986 a
	2.2	1834 a	9.5 a	173 a	49.6 a	908 a
	3.3	1756 a	8.7 a	154 a	50.0 a	875 a
	6.6	1826 a	8.9 a	163 a	51.3 a	936 a
	9.9	1775 a	9.3 a	166 a	49.3 a	875 a

Means within column by trial followed by the same letter are not significantly different ($P > 0.05$; Duncan's[1955] multiple range test). CP, crude protein; IVDDM, *in vitro* digestible dry matter; DM, dry matter yield; DDM, digestible dry matter yield; CP, crude protein yield.

[a] The 1984 data were taken in a time frame equivalent to the 1983 Trial 2.

Table 7. The effects of varying S. frugiperda densities on % CP and IVDDM and yields of DM, DDM and CP in 'Alicia' bermudagrass.

	Larvae per 0.1 m^2	DM Yield kg/ha	CP %	CP kg/ha	IVDDM %	IVDDM kg/ha DDM
Trial 1	1983					
	0	2499 a	19.2 a	482 a	56.9 a	1425 a
	1.1	2100 a	17.7 a	370 a	55.4 b	1167 a
	2.2	2272 a	17.9 a	404 a	55.4 b	1261 a
	3.3	1991 a	17.7 a	356 a	55.2 b	1103 a
	6.6	1911 a	18.0 a	349 a	55.1 b	1057 a
	9.9	1756 a	17.5 a	312 a	53.9 b	952 a
Trial 2	1983					
	0	3811 a	17.8 a	677 a	53.8 a	2054 a
	1.1	3940 a	17.6 a	697 a	52.8 b	2028 a
	2.2	3775 a	17.5 a	658 a	52.9 ab	2002 a
	3.3	3609 a	16.3 a	582 a	52.2 b	1882 a
	6.6	3829 a	16.5 a	635 a	52.1 b	2008 a
	9.9	3656 a	17.1 a	623 a	52.6 b	1992 a
Trial 1	1984[a]					
	0	2328 a	7.7 bc	181 a	50.1 a	1162 a
	1.1	2276 a	7.2 c	162 a	47.5 a	1079 a
	2.2	2316 a	7.2 c	167 a	48.5 a	1122 a
	3.3	2322 a	7.9 bc	184 a	48.9 a	1131 a
	6.6	2183 a	8.8 ab	189 a	48.5 a	1056 a
	9.9	2182 a	8.9 a	194 a	49.1 a	1070 a

Means within column by trial followed by the same letter are not significantly different ($P > 0.05$; Dunacn's[1955] multiple range test). CP, crude protein; IVDDM, *in vitro* digestible dry matter; DM, dry matter yield; DDM, digestible dry matter yield; CP crude protein yield.

[a] The 1984 data were taken in a time frame equivalent to the 1983 Trial 2.

During the first and second trial in 1983, DDM yields of 'Coastal' were higher in the control plots than observed in the other treatments (Table 6). Digestible dry matter yields of 'Coastal' plots with densities of 3.3, 6.6, and 9.9 FAW larvae per 0.1 m^2 were significantly lower than yields in the control plots during both trials in 1983 (Table 6). The lower DDM yield is due to lower IVDDM as well as to lower DM yield. A density of 2.2 larvae per 0.1 m^2 also significantly reduced DDM during the first trial. Crude protein yields of all infested 'Coastal' plots were significantly lower than the control plots during the first trial in 1983, but only plots infested with a density of 9.9 larvae per 0.1 m^2 showed significantly lower CP yield than the control plot during the second trial. The lower CP yield is due mostly to DM yield because the % CP had not changed that much. In 1984, there were no significant differences in DDM and CP yields between the 'Coastal' control and infested 'Coastal' plots, however, yields were generally lower in the infested plots than the controls. Dry digestible matter and CP yields of 'Alicia' were generally lower in the infested plots than in the control plots during all trials, but the differences were not significant (Table 7).

Concentrations of NDF, ADF, CELL, and AIL in 'Coastal' (Appendix, Table 7) and 'Alicia' (Appendix, Table 8) were not consistently affected by FAW feeding and, thus, direct correlations between infestation level and resulting impact on any one of these quality parameters cannot be made.

Equations used to predict yield loss due to various S. frugiperda density levels are as follows: 'Coastal' ($y = 0.15765 X - 0.0010 X^2$; yield loss = 0.07 X number of larvae per 0.1 m^2; $r^2 = 0.70$, df = 1, 17, $P < .01$) and Alicia (yield loss = 0.04 X number of larvae per 0.1 m^2; r^2 =

0.47, df = 1, 17, $P < .01$) (Appendix, Table 9). The cost of control was estimated to be $6.74/ha (Boucher & Huffman 1983). Economic injury level (larvae per 0.1 m^2) for FAW on 'Coastal' bermudagrass is influenced by the commodity price (Table 8). Thus, the *S. frugiperda* economic injury level would be 8 fourth and fifth instar larvae per 0.1 m^2 on 'Coastal' bermudagrass. Because the calculated EIL for 'Alicia' bermudagrass was above the highest infestation rate (9.9 larvae/0.1 m^2), an EIL cannot be accurately predicted for this grass from this study.

DISCUSSION

Fall armyworm larvae adversely affected bermudagrass forage quality and yield; however, results indicate that there were differences between varieties. Dry matter yields of 'Coastal' bermudagrass decreased linearly with increasing FAW density during both trials in 1983 (Table 6). Digestible dry matter and CP yields showed the same pattern as DM yields. The impact of FAW feeding on the quality and yield of 'Coastal' is supported by previous studies on alfalfa. Liu & Fick (1975) reported that during the peak alfalfa weevil, *Hypera postica* (Gyllenhal), larval feeding, *in vitro* true digestibility and CP concentration of alfalfa leaves decreased with higher populations; however, weevil defoliation did not have a significant influence on leaf percentage or the quality of the total herbage (leaf and stem) because stem growth was suppressed. Hintz et al. (1976) also found that % IVDMD and CP were significantly reduced as alfalfa weevil larval populations increased. Yield reductions were also observed during both studies. Buntin and Pedigo (1985) showed defoliation of alfalfa stubble by the variegated cutworm,

Table 8. Economic injury level (EIL) (larvae/0.1 m^2) of *S. frugiperda* on 'Coastal' bermudagrass.

Commodity price ($/metric ton)	*S. frugiperda* EIL[a] 'Coastal'
51	8.1
54	7.6
55	7.4
59	6.9
66	6.2

[a] Control costs ($3.58/ha) are based on a ground application of 0.56 kg/ha of carbaryl (Sevin WP), plus costs ($3.16/ha) for application.

Peridroma saucia (Hubner), brought about higher forage quality, measured in terms of % CP and IVDMD, but lower DM yield.

In contrast, quality and DM yields of 'Alicia' were not significantly affected by FAW feeding within the range of densities studied (Table 7). 'Alicia' showed a higher degree of resistance to FAW than 'Coastal'. This was indicated by a lower damage rating index (Table 1), higher number of leaves per stem (Appendix C, Tables 2 and 3), and DM yields (Tables 6 and 7). 'Alicia' has been reported to be a resistant variety to FAW in laboratory consumption studies (Combs & Valerio 1980, Quisenberry & Wilson 1985). 'Alicia' also has lower digestibility and higher non-digestible content than 'Coastal' (Marvin 1976, Montgomery et al. 1979) factors which make it less suitable for larval development. Lynch et al. (1986) found a significant correlation between high bermudagrass % CP and IVDMD and higher FAW larval and pupal weights and reduced duration of larval and pupal development.

The differences in quality and yield observed in the second trial in 1983 and the trial in 1984 cannot be explained totally by FAW stress on the plants. A plant's response to insect injury is influenced by a number of factors including time of injury, plant part injured, intensity of injury, and environmental conditions (Fenemore 1982). During the second trial in 1983, rainfall (9.4 cm) was higher after larvae had been removed from the plots than the total amount of rainfall received during the first trial (1.5 cm) in 1983 and the 1984 trial (0.5 cm). The rainfall received during the second trial promoted regrowth as indicated by increases in the numbers of leaves per stem, plant height, and leaf area; therefore, the highest yields were obtained during this trial. Quality and yield of 'Coastal' and 'Alicia' were lowest during the 1984 trial. The NDF concentrations were approximately 10 and 13% higher than found in 1983. The CP concentration was only half the levels observed during both trials in 1983. Plants had fewer leaves and a greater proportion of stem per plant. Crude protein concentration is normally higher in leaves than in stems (Mowat et al. 1965). Thus, the high % NDF and low % CP of plants in 1984 resulted in the low % IVDDM. These observations are supported by Rainwater (1975) who reported more digestible forage varieties have lower NDF concentrations.

The quantitative measurement of plant stress by FAW feeding permits the calculation of EIL and ET of fourth and fifth instar larvae on 'Coastal' bermudagrass. Stern et al. (1979), Stone & Pedigo (1972), and Pedigo et al. (1986) defined EIL as the population density that will cause an amount of injury which will justify control. Thus, ET is the populaiton density where control measures should be initiated to prevent the population from reaching the EIL. The factors needed to estimate EILS are market value, management cost, injury per insect density, and host damage per unit of injury (Stone & Pedigo 1972, Pedigo et al. 1986). In our study, EIL for 'Coastal' bermudagrass was 8 fourth and fifth instar larvae per 0.1 m^2 (Table 8). The bermudagrass hay price was $54 per metric ton in 1983 when our study was conducted; however, as hay price increases the EIL decreases (Table 8). These data are similar to the EIL reported by Martin et al. (1980) of 5 larvae per 0.1 m^2 using a hay price of $0.055 per kg and $12.35 per ha control cost. Alvarado et al. (1983) reported the EIL of 0.8 third and fourth instar larvae per m^2 and 1.5 fifth and sixth instar larvae per m^2 using a hay price of $0.092 per kg and control cost of $6.13 per ha. There appears to be an inflation in loss estimates due to an error in their sampling technique; the researchers kept adding larvae to maintain larval density levels.

We suggest an ET of 4 fourth and fifth instar larvae per 0.1 m^2 for 'Coastal' bermudagrass. Because it is desirable to control the pest population before it exceeds EIL (Stern et al. 1959), the use of the ET for FAW would allow initiation of control before the population could reach damaging levels.

Although 'Alicia' showed a higher degree of resistance to FAW feeding, 'Alicia' was inferior to 'Coastal' in both forage quality and yield production; however, from a physiological perspective, 'Alicia' is more winter-hardy than 'Coastal' (Monroe 1978). We suggest that 'Alicia' might be crossed with other bermudagrasses having higher quality and yield potential to obtain a variety with good agronomic characteristics, and resistance to FAW.

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SUMMARY AND CONCLUSIONS

Bermudagrass, Cynodon dactylon (L.) Pers. is a warm-season perennial grass used primarily for hay and grazing in the southern United States.The fall armyworm (FAW), Spodoptera frugiperda (J. E. Smith), is one of the major insect pests of bermudagrass. Although FAW is a sporadic insect pest, losses may be tremendous. Since a number of bermudagrasses have been bred for good agronomic characteristics, these grasses also need to be screened for resistance to FAW. Consumption, utilization, preference, and host suitability parameters were used to determine development and survivorship to the adult stage of FAW fed nine bermudagrasses and to categorize the level of resistance to FAW feeding in each grass. The results demonstrated that the susceptible bermudagrasses were 'Tifton 78', 'OSU 74 X 12-1', and 'Grazer'. The bermudagrass #1 R12P5, 'Coastal', 'Tifton 292', 'OSU 74 X 11-2', and 'Tifton 44' were intermediately resistant. 'OSU 71 X 6-7' was the only bermudagrass categorized as resistant to FAW. However, further work is needed to elucidate whether allelochemicals provide for the resistance observed. For plant breeding programs, it is suggested that 'OSU 71 X 6-7' be crossed with agronomically adapted varieties to obtain a hybrid that contains positive agronomic characteristics and some measure of FAW resistance.

Resistance levels appeared to fluctuate somewhat as the quality of host plant changed and, in particular, as non-digestible fractions increased. Field-grown grasses were less suitable to FAW development than those reared in the greenhouse. The quality of grasses grown under field conditions declined more rapidly than the quality of grasses grown in the greenhouse. Greenhouse-grown grasses had a higher percentage of

IVDDM and lower non-digestible fractions than grasses grown in the field. Feeding larvae higher quality bermudagrass resulted in higher larval weights and shorter development times. These results suggest that initial studies to evaluate bermudagrass for resistance to FAW can be conducted in the greenhouse but should be confirmed with field studies.

Fall armyworm feeding at varying densities in field plots resulted in significant quality and yield losses in 'Coastal' bermudagrass, but not 'Alicia'. Digestible dry matter and crude protein yield losses ranged from 245 and 72 kg/ha, respectively. Economic injury levels were established using a hay price of $54 per metric ton and cost of control of $6.74 per ha. The economic injury level for 'Coastal' was 8 fourth and fifth instar larvae per 0.1 m^2. From these data an economic threshold of 4 fourth and fifth instar larvae per 0.1 m^2 for 'Coastal' was derived. This level should enable growers to more effectively manage FAW on bermudagrass. 'Alicia' showed more resistance to FAW feeding than 'Coastal' as indicated by a lower damage rating and lower yield and quality losses.

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APPENDIX

Table 1. Bermudagrass variety and strain descriptions.

Bermudagrass	Year released	Pedigree history
'Coastal'	1943	F1 hybrid between common plant 'Tifton, Georgia, and plant from the Union of South Africa
'Tifton 44'	1978	Sterile F1 hybrid from a cross 'Coastal' and a plant introduction from Germany
'Tifton 78'	1984	Sterile F1 hybrid from a cross of 'Tifton 44 and Callie bermudagrass
'Tifton 292'		PI 290884
#1 R12P5	NR[a]	Cross between 'Tifton 44 and 'Tifton 292
'Grazer'	1985	F1 hybrid (PI 255450 X PI 320876) of plant from Kenya and Italy
'OSU 71 X 6-7'	NR	F1 hybrid (Accession 12165 X 81-53) X SS-16
'OSU 74 X 11-2'	NR	F1 hybrid (Accession 12165 X SS-27)
'OSU 74 X 12-1'	NR	F1 hybrid (Accession 12165 X 9945) X IN35-1

[a] Not yet released.

Table 2. Leaf area index ($cm^2/0.015\ m^2$) of 'Coastal' and 'Alicia' bermudagrasses as affected by *S. frugiperda* feeding, 1984.

Larvae per 0.1 m^2	Days after infesattion 6(7)	12(14)	18(21)	24(28)
'Coastal'				
0	2.7 a	3.9 a	2.6 a	4.4 a
1.1	1.9 ab	2.4 a	3.3 a	3.6 a
2.2	1.4 b	2.6 a	3.4 a	3.6 a
3.3	1.3 b	2.1 a	2.5 a	3.4 a
6.6	1.5 b	1.9 a	2.9 a	2.7 a
9.9	0.8 b	2.6 a	3.8 a	3.8 a
'Alicia'				
0	2.0 a	2.9 a	4.1 a	3.9 a
1.1	1.3 a	2.8 a	3.6 a	3.3 a
2.2	1.5 a	2.3 a	3.4 a	4.1 a
3.3	1.1 a	1.6 a	3.7 a	3.2 a
6.6	1.0 a	1.7 a	2.9 a	3.0 a
9.9	1.4 a	2.1 a	3.0 a	4.1 a

Means within column by variety followed by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test).

Table 3. Leaves/stem of 'Coastal' bermudagrass as affected by *S. frugiperda* feeding.

	Larvae per 0.1 m^2	Days after infestation[a] 6(7)	12(14)	18(21)	24(28)
Trial 1-1983					
	0	6.7 a	8.9 a	10.0 a	11.1 a
	1.1	7.6 a	7.4 a	9.0 a	11.7 a
	2.2	6.2 a	8.0 a	7.3 a	10.3 a
	3.3	6.9 a	7.2 a	8.7 a	9.5 a
	6.6	6.2 a	8.3 a	10.0 a	9.4 a
	9.9	6.1 a	8.1 a	9.0 a	10.5 a
Trial 2-1983					
	0	8.1 a	13.2 a	14.3 a	10.1 a
	1.1	9.3 a	12.1 a	9.8 a	8.6 a
	2.2	8.3 a	11.2 a	11.4 a	9.3 a
	3.3	7.3 a	9.5 a	10.8 a	8.4 a
	6.6	8.9 a	10.8 a	12.2 a	8.5 a
	9.9	7.1 a	10.0 a	12.3 a	9.2 a
Trial 1-1984					
	0	7.9 a	10.4 a	8.9 a	7.8 a
	1.1	6.5 a	7.3 a	9.9 a	8.8 a
	2.2	6.8 a	9.2 a	9.0 a	9.7 a
	3.3	5.3 a	8.6 a	7.1 a	8.2 a
	6.6	6.7 a	7.7 a	9.9 a	8.9 a
	9.9	6.0 a	8.6 a	10.4 a	9.1 a

Means within column by trial followed by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test).

[a] Sampling periods 6, 12, 18, 24 days after infestation in 1983 during two trials; 7, 14, 21, 28 days in 1984.

Table 4. Leaves/stem of 'Alicia' bermudagrass as affected by *S. frugiperda* feeding.

Larvae per 0.1 m^2	Days after infestation[a] 6(7)	12(14)	18(21)	24(28)
Trial 1-1983				
0	11.5 a	12.7 a	16.9 a	17.7 a
1.1	12.2 a	13.7 a	14.8 a	16.9 a
2.2	13.9 a	11.9 a	17.5 a	17.5 a
3.3	12.2 a	13.4 a	14.8 a	13.1 a
6.6	12.5 a	12.6 a	17.4 a	12.9 a
9.9	12.8 a	12.7 a	14.7 a	15.9 a
Trial 2-1983				
0	13.5 a	17.7 a	17.5 a	11.3 a
1.1	17.0 a	18.6 a	14.8 a	9.8 a
2.2	17.1 a	16.4 a	17.4 a	9.8 a
3.3	12.0 a	16.4 a	15.5 a	10.3 a
6.6	11.7 a	16.5 a	11.6 a	11.3 a
9.9	10.6 a	16.3 a	15.9 a	10.8 a
Trial 1-1984				
0	7.3 a	10.8 a	13.0 a	14.5 a
1.1	8.4 a	10.1 a	12.7 a	11.5 a
2.2	7.7 a	9.6 a	10.5 a	11.3 a
3.3	9.5 a	10.1 a	10.8 a	12.0 a
6.6	7.8 a	11.1 a	12.1 a	11.5 a
9.9	7.7 a	10.2 a	12.9 a	12.1 a

Means within column by trial followed by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range

[a] Sampling periods 6, 12, 18, 24 days after infestation in 1983 during two trials; 7, 14, 21, 28 days in 1984.

Table 5. Dry matter yield (kg/ha) of 'Coastal' bermudagrass as affected by *S. frugiperda* feeding.

	Larvae per 0.1 m^2	Days after infestation[a] 6(7)[b]	12(14)	18(21)	24(28)
Trial 1-1983					
	0	1372 a	2026 a	2012 a	3110 a
	1.1	1050 ab	1292 b	1396 b	2468 ab
	2.2	1164 ab	1556 ab	1222 b	2250 b
	3.3	948 ab	1212 b	1404 b	2212 b
	6.6	766 b	1118 b	1250 b	2278 b
	9.9	1008 ab	1186 b	1100 b	2468 b
Trial 2-1983					
	0	1614 a	2562 a	2942 a	4166 a
	1.1	1654 a	2420 a	3182 a	3914 a
	2.2	1818 a	2414 a	3530 a	3372 a
	3.3	1414 a	2744 a	3350 a	3194 a
	6.6	1426 a	2318 a	2612 a	3044 a
	9.9	1662 a	2374 a	2324 a	3338 a
Trial 1-1984					
	0	1490 a	2168 a	2316 a	3084 a
	1.1	1370 ab	1646 a	2416 a	3552 a
	2.2	1054 abc	1686 a	2666 a	2764 a
	3.3	926 bc	1586 a	2222 a	3082 a
	6.6	822 c	1684 a	2026 a	2962 a
	9.9	778 c	1582 a	2190 a	2862 a

Means within column by trial followed by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test).

[a] Sampling periods 6, 12, 18, 24 days after infestation in 1983 during two trials; 7, 14, 21, 28 days in 1984.

[b] Dry matter yield reported as kg/ha was based on data collected from g/0.06 m^2 in 1983 and g/0.015 m^2 in 1984.

Table 6. Dry matter yield (kg/ha) of 'Alicia' bermudagrass as affected by *S. frugiperda* feeding.

	Larvae per 0.1 m^2	Days after infestation[a]			
		6(7)[b]	12(14)	18(21)	24(28)
Trial 1-1983					
	0	1170 a	1572 a	2028 a	2702 a
	1.1	1098 a	1148 a	1606 a	2122 a
	2.2	1198 a	1316 a	1688 a	2336 a
	3.3	1070 a	1242 a	1412 a	2118 a
	6.6	1012 a	1248 a	1374 a	2028 a
	9.9	930 a	1072 a	1288 a	2672 a
Trial 2-1983					
	0	2228 a	3334 a	3834 a	6088 a
	1.1	2560 a	3446 a	3380 a	5282 a
	2.2	1926 a	3038 a	4842 a	5420 a
	3.3	2014 a	3400 a	3818 a	5594 a
	6.6	2270 a	2998 a	4254 a	5590 a
	9.9	2032 a	3306 a	4018 a	5138 a
Trial 1-1984					
	0	1776 a	2226 a	2532 a	2590 a
	1.1	1430 a	2000 a	2938 a	3178 a
	2.2	1092 a	1672 a	2664 a	3318 a
	3.3	1218 a	1942 a	2750 a	3190 a
	6.6	984 a	1538 a	2174 a	2640 a
	9.9	1116 a	1936 a	2390 a	3282 a

Means within column by trial followed by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test).

[a] Sampling periods 6, 12, 18, 24 days after infestation in 1983 during two trials; 7, 14, 21, 28 days in 1984.

[b] Dry matter yield reported as kg/ha was based on data collected from g/0.06 m^2 in 1983 and g/0.015 m^2 in 1984.

Table 7. The effects of varying S. frugiperda densities on NDF, ADF, CELL and AIL concentrations (%) in 'Coastal' bermudagrass.

	Larvae per 0.1 m^2	% Concentration NDF	ADF	CELL	AIL
Trial 1-1983					
	0	67.4 a	34.6 a	25.6 a	4.2 a
	1.1	67.9 a	34.8 a	26.3 a	4.3 a
	2.2	67.5 a	34.8 a	25.6 a	4.4 a
	3.3	67.9 a	34.9 a	26.2 a	4.5 a
	6.6	67.6 a	34.8 a	25.7 a	4.3 a
	9.9	67.8 a	34.8 a	26.1 a	4.4 a
Trial 2-1983					
	0	67.9 a	34.6 a	26.7 a	4.2 a
	1.1	68.1 a	34.7 a	26.6 a	4.3 a
	2.2	68.1 a	34.9 a	26.6 a	4.4 a
	3.3	68.3 a	34.9 a	26.4 a	4.5 a
	6.6	66.5 b	34.7 a	26.1 a	4.2 a
	9.9	66.3 b	34.6 a	25.9 a	4.2 a
Trial 1-1984					
	0	77.7 a	40.0 a	31.9 a	4.5 a
	1.1	78.1 a	40.6 a	31.9 a	4.5 a
	2.2	77.5 a	40.9 a	32.6 a	4.6 a
	3.3	77.8 a	40.8 a	32.2 a	4.5 a
	6.6	76.9 a	40.4 a	32.2 a	4.2 a
	9.9	77.8 a	40.9 a	32.7 a	4.4 a

Means within column by trial followed by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test). NDF, neutral detergent fiber; ADF, acid detergent fiber; CELL, cellulose; AIL, acid insoluble lignin.

Table 8. The effects of varying S. frugiperda densities on NDF, ADF, CELL and AIL concentrations (%) in 'Alicia' bermudagrass.

	Larvae per 0.1 m^2	% Concentration			
		NDF	ADF	CELL	AIL
Trial 1-1983					
	0	68.2 a	35.1 a	24.7 a	4.6 a
	1.1	69.2 a	35.5 a	25.4 a	4.8 a
	2.2	69.1 a	35.6 a	25.0 a	4.9 a
	3.3	68.9 a	35.4 a	25.0 a	4.9 a
	6.6	69.2 a	35.9 a	24.7 a	5.1 a
	9.9	68.4 a	35.5 a	24.6 a	4.9 a
Trial 2-1983					
	0	66.7 a	34.9 b	25.4 b	4.4 b
	1.1	67.2 a	35.3 a	25.5 ab	4.7 a
	2.2	67.1 a	35.3 a	25.6 ab	4.7 a
	3.3	67.4 a	35.3 a	26.1 a	4.7 a
	6.6	67.6 a	35.6 a	25.3 b	4.9 a
	9.9	67.5 a	35.5 a	25.3 b	4.8 a
Trial 1-1984					
	0	79.5 a	41.5 a	32.9 a	4.2 b
	1.1	79.7 a	42.7 a	33.3 a	4.8 a
	2.2	79.2 a	42.3 a	33.4 a	4.8 a
	3.3	79.9 a	41.7 a	32.7 a	4.6 a
	6.6	79.3 a	41.7 a	33.1 a	4.7 a
	9.9	78.9 a	41.6 a	32.9 a	4.7 a

Means within column by trial followed by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test). NDF, neutral detergent fiber; ADF, acid detergent fiber; CELL, cellulose; AIL, acid insoluble lignin.

Table 9. The economic injury level, based on five hay prices ($/metric ton), of *S. frugiperda* larvae feeding on 'Coastal' and 'Alicia' bermudagrasses.

Variety	Larvae per 0.1 m^2	Yield loss (g/0.5 m^2)	Yield loss (kg/ha)	Hay price ($/metric ton) 51	54	55	59	66
				Expected economic loss ($/ha)				
'Coastal'	1	0.07	18.12	0.83	0.89	0.91	0.98	1.09
	2	0.15	36.24	1.67	1.78	1.81	1.96	2.17
	3	0.22	54.36	2.50	2.66	2.72	2.94	3.26
	4	0.29	72.48	3.33	3.55	3.62	3.91	4.35
	5	0.37	90.60	4.17	4.44	4.53	4.89	5.44
	6	0.44	108.72	5.00	5.32	5.44	5.87	6.52
	7	0.51	126.84	5.83	6.22	6.34	6.85	7.61
	8	0.59	144.96	6.67	7.10	7.25	7.83	8.70
	9	0.66	163.08	7.50	7.99	8.15	8.80	9.78
	10	0.73	181.20	8.34	8.88	9.06	9.78	10.87
'Alicia'	1	0.04	9.55	0.44	0.47	0.48	0.52	0.57
	2	0.08	19.10	0.88	0.94	0.95	1.03	1.15
	3	0.12	28.65	1.32	1.40	1.43	1.55	1.72
	4	0.15	38.20	1.76	1.87	1.91	2.06	2.29
	5	0.19	47.75	2.20	2.34	2.39	2.58	2.86
	6	0.23	57.30	2.64	2.81	2.86	3.09	3.44
	7	0.27	66.84	3.07	3.28	3.34	3.61	4.01
	8	0.31	76.39	3.51	3.74	3.82	4.13	4.58
	9	0.35	85.94	3.95	4.21	4.30	4.64	5.16
	10	0.39	95.49	4.39	4.68	4.77	5.16	5.73
	11	0.43	105.04	4.83	5.15	5.25	5.67	6.30
	12	0.46	114.59	5.27	5.61	5.73	6.19	6.88
	13	0.50	124.14	5.71	6.08	6.21	6.70	7.45
	14	0.54	133.69	6.15	6.55	6.68	7.22	8.02
	15	0.58	143.24	6.59	7.02	7.16	7.73	8.59

[a] Control costs ($3.58/ha) are based on a ground application of 1.1 kg/ha of carbaryl (Seven WP), plus costs ($3.16/ha) for application.

VITA

Tasanee Jamjanya is the daughter of Col. Thanom and Wanni Jamjanya. She was born in Nakornsrithammarat, Thailand, in 1949. She graduated from Benchamarachuthit High School, Nakornsrithammarat, Thailand, in 1966. She earned a Bachelor of Science in Entomology at Kasetsart University, Thailand in 1970. She then persued her studies under the support of Rockyfeller Foundation at Kasetsart University and received a M. S. in Entomology in 1975. During 1975-1983, she was appointed as an instructor at Department of Entomology and Plant Pathology, Khon Kaen University, Thailand. She is presently a candidate for the Doctor of Philosophy degree in the Department of Entomology at Louisiana State University.

DOCTORAL EXAMINATION AND DISSERTATION REPORT

Candidate: Tasanee Jamjanya

Major Field: Entomology

Title of Dissertation: Consumption, Utilization, Biology, and Economic Injury Levels of Fall Armyworm, Spodoptera frugiperda (J. E. Smith) on Selected Bermudagrasses.

Approved:

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Major Professor and Chairman

Dean of the Graduate School

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Date of Examination:

March 18, 1987